JANUARY 1960

VOL. 52 • NO. 1

Journal

AMERICAN WATER WORKS ASSOCIATION

Banker awaits new deposit-as dredging rig scoops pipe trench under Meramec River

In this issue:

AMERICA'S GREATEST CHALLENGE Grayson

PUERTO RICO AQUEDUCT AND SEWER AUTHORITY Urrutia, Jordan

UTILITY LONG-RANGE PLANNING Steel

JUDICIAL CONCEPTS OF UTILITY LIABILITY Remus

TRUE COST OF ACCIDENTS Sopp

CROSS-CONNECTION CONTROL Shillinger, Fassnacht, Dempster, Derby, Allen, Ongerth

MATERIALS FOR METER MANUFACTURE Barrett, Reichel

VALVE OPERATION AND WATER HAMMER Kerr, McPherson

PIPE AND INTAKE INSTALLATIONS Norman, Schmid, Bauhahn, Argo

ADVANCES IN USE OF FLUORSPAR Maier

MAGNESIUM REDUCTION Tuepker, Hartung

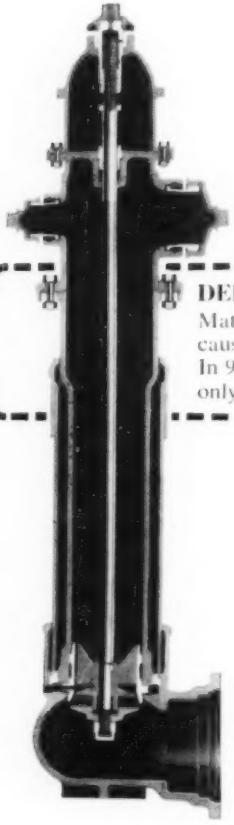
ANALYTICAL METHODS FOR HEAVY METALS Kroner, Ballinger, Kramer

CHLORINE AND ALUM SUPPLY Joint Committee Reports

SHORT FILTER RUNS Gamet, Rademacher

1960 AWWA CONFERENCE
Bal Harbour, May 15–20

ONLY MATHEWS HAS ALL THE DESIRABLE FEATURES



What do you look for in a hydrant? Dependability? . . . replaceable barrel? . . . conventional packing? . . . "O" ring seal? . . . stop nut to prevent stem from buckling? We could double this list and still not cover all the features we build into Mathews Hydrants *by design*. Mathews has them all.

DEPENDABILITY

Mathews Hydrants are always ready for service, because their design is fundamentally sound and simple. In 90 years we have never changed the basic design—only refined it, by detail.

AND ALL THESE OTHER FEATURES, TOO:

All working parts contained in replaceable barrel • Head can be faced in any direction • Replaceable head • Any nozzles you specify • Nozzle levels raised or lowered without excavating • Leakproof because stuffing box is cast integral with nozzle section • Operating thread only part requiring lubrication • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Available with bell, mechanical joint or flange pipe connections

Conform to latest AWWA specifications

R. D. WOOD COMPANY

Public Ledger Building, Independence Square, Philadelphia 5, Pa.

Manufacturers also of Mathews Flange Barrel Hydrants, R. D. Wood Hydrants, R. D. Wood Gate Valves, and "Sand-Spun" Pipe (centrifugally cast in sand molds)

Journal

AMERICAN WATER WORKS ASSOCIATION

2 PARK AVE., NEW YORK 16, N.Y. • Phone: MUrray Hill 4-6686

January 1960

Vol. 52 • No. 1

Contents

Water Supply—America's Greatest Challenge ..... LAUREN W. GRAYSON 1
Puerto Rico Aqueduct and Sewer Authority ..... RAFAEL V. URRUTIA 6
Discussion ..... HARRY E. JORDAN 12
Long-Range Planning by Water Utilities ..... ERNEST W. STEEL 13
Changes in Judicial Concepts of Utility Liability ..... GERALD REMUS 19
The True Price of Accidents ..... GEORGE C. SOPP 25
Cross-Connection Hazards and Controls
WILLIAM D. SHILLINGER & GEORGE G. FASSNACHT 36
New Discount System for AWWA Publications 40
Control and Elimination of Cross Connections—*Panel Discussion*
ANDREW T. DEMPSTER, RAY L. DERBY, E. JERRY ALLEN & HENRY J. ONGERTH 41
Study of Materials to Replace Copper-Base Alloys in Meter Manufacture
Introduction and Summary ..... HERBERT F. BARRETT 53
Armour Foundation Report ..... RICHARD C. REICHEL 56
Reprints Available 64
Effect of Valve Operation on Water Hammer ..... S. LOGAN KERR 65
Discussion ..... M. B. MCPHERSON 72
Water Main Installation Across the Meramec River ..... E. OLIVER NORMAN 76
Importance of Thrust Blocks for Pipe Installations
GEORGE G. SCHMID & ELMER E. BAUHAHN 81
AWWA Meter Manual Available 87
Design and Installation of Intakes for Canadian Supplies ..... JOHN W. ARGO 88
Advances in the Use of Fluorspar for Fluoridation ..... F. J. MAIER 97
Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction
JONATHAN L. TUEPKER & HERBERT O. HARTUNG 106
Evaluation of Laboratory Methods for Analysis of Heavy Metals in Water
ROBERT C. KRONER, DWIGHT G. BALLINGER & HARRY P. KRAMER 117
Chlorine Supply and Use in Water and Sewage Treatment Plants
JOINT COMMITTEE REPORT 125
Alum Supply and Use in Water Treatment Plants ..... JOINT COMMITTEE REPORT 135
Study of Short Filter Runs With Lake Michigan Water
MERRILL B. GAMET & JOHN M. RADEMACHER 137
Coagulant Aids for Potable-Water Treatment 152

Departments

Officers and Directors ..... *2 P&R*
Coming Meetings ..... *6 P&R*
Percolation and Runoff ..... *35 P&R*
Employment Information ..... *50 P&R*
Service Lines ..... *52 P&R*
Condensation ..... *62 P&R*
Reading Meter ..... *82 P&R*
Correspondence ..... *92 P&R*

RAYMOND J. FAUST, *Secretary* — ERIC F. JOHNSON, *Director of Publications*
LAWRENCE FARBER, *Managing Editor* — ROBERT A. NYE, *Production Manager*
ARNE E. GUBRUD, *Associate Editor* — MILTON HOROWITZ, *Assistant Editor*

Journal AWWA is published monthly at Prince & Lemon Sts., Lancaster, Pa., by the Am. Water Works Assn., Inc., 2 Park Ave., New York 16, N.Y. Second-class postage paid at Lancaster, Pa. Authorized Aug. 6, 1918. $8.00 of members' dues are applied as a subscription to the JOURNAL; additional single copies to members—60 cents; single copies to non-members—85 cents. Indexed annually in December; and regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm edition (for JOURNAL subscribers only) by University Microfilms, Ann Arbor, Mich.

© 1960, by the American Water Works Association, Inc. Made in U.S.A.

AWWA Officers and Directors

President	LAUREN W. GRAYSON	*Past-President*	LEWIS S. FINCH
Vice-President	C. F. WERTZ	*Treasurer*	WILLIAM J. ORCHARD
Ch. W.W. Practice Com.	LOUIS R. HOWSON	*Secretary*	RAYMOND J. FAUST
Ch. W.W. Admin. Com.	WENDELL R. LADUE	*Asst. Secretary*	ERIC F. JOHNSON
Ch. Publication Com.	E. SHAW COLE	*Asst. Secretary*	JAMES B. COREY

Officers of the Sections

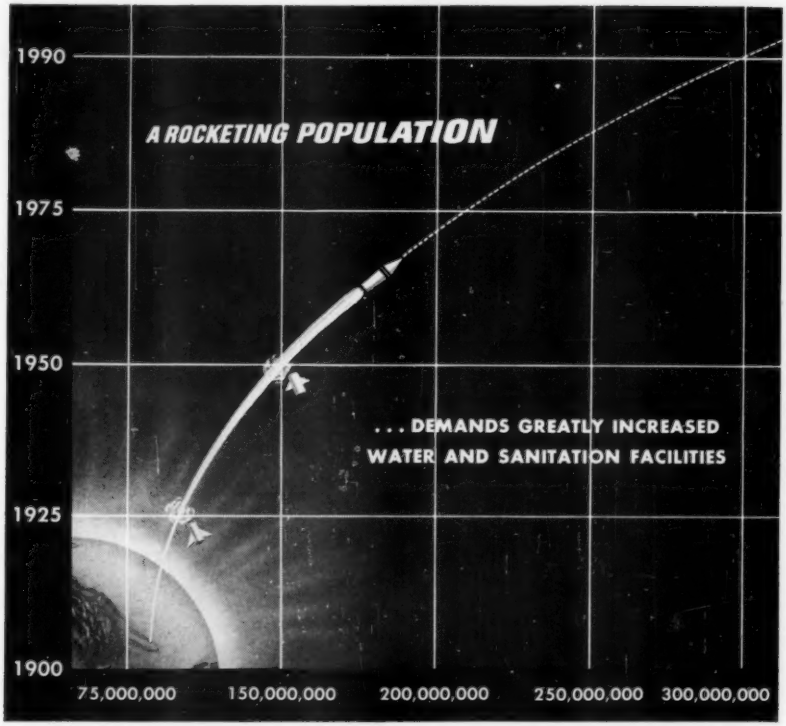
Section	*Director*	*Chairman*	*Vice-Chairman*	*Secretary-Treasurer*
Alabama-Miss.	J. L. Haley	Fred Scott Jr.	Charles Mathews	Ernest Bryan
Arizona	L. O. Gardner	H. C. Bigglestone	R. E. Polenske	A. D. Cox
California	C. P. Harnish	J. N. Spaulding	M. K. Socha	F. F. Watters
Canadian	C. S. Anderson	G. R. Davis	J. D. Kline	A. E. Berry
Chesapeake	B. L. Werner	V. W. Faivre	R. L. Orndorff	C. J. Lauter
Cuban	L. H. Daniel	R. Garcia Montes	L. de Goicochea	L. H. Daniel
Florida	F. A. Eidsness	H. T. Skaggs	C. H. Stanton	J. G. Simmons
Illinois	H. H. Gerstein	Armon Lund	J. C. Vaughn	D. W. Johnson
Indiana	J. L. Ford Sr.	H. R. Wilke	J. B. Wilson	C. H. Canham
Intermountain	C. W. Wilson	R. J. Huckabee	W. C. Hague	M. W. Snell
Iowa	M. K. Tenny	R. H. Thompson	H. F. Seidel	J. J. Hail
Kansas	R. H. Hess	O. K. Brandon	R. L. Chandler	H. W. Badley
Kentucky-Tenn.	J. J. Davis	R. L. Lawrence Jr.	J. D. Boxley	H. F. Mount
Michigan	H. O. Self	H. L. Keinath	Tony Eikey	T. L. Vander Velde
Missouri	W. B. Schworm	L. E. Martin	F. E. Dolson	W. A. Kramer
Montana	D. S. Thomas	C. W. Brinck	E. R. Waldo	A. W. Clarkson
Nebraska	G. H. Beard	E. C. Wagner	R. E. Arraj	J. J. Rossbach Jr.
New England	K. R. Kennison	C. L. Ahlgren	A. J. Minkus	R. M. Soule
New Jersey	R. E. Bonyun	L. W. Klockner	P. E. Pallo	A. F. Pleibel
New York	J. M. Diven	J. J. Meehan	C. M. Taylor	Kimball Blanchard
North Carolina	J. R. Purser Jr.	W. E. Long Jr.	R. E. Ebert	T. Z. Osborne
North Central	L. H. Coult	C. M. Bach	W. J. Bell	C. A. Flack
Ohio	D. D. Heffelfinger	Pierce Bailey	Franklin Ruck	J. H. Bass
Pacific Northwest	W. H. Berkeley	J. L. Geren	A. H. Perry	F. D. Jones
Pennsylvania	S. S. Baxter	K. E. Shull	H. E. Beckwith	L. S. Morgan
Rocky Mountain	J. O. Jones	J. M. Hunter Jr.	Ernest Martinez	H. F. Kepner
Southeastern	C. C. Lanford	L. R. Simonton	O. M. Fuller	N. M. deJarnette
Southwest	K. F. Hoefle	Henry Graeser	G. T. Kellogg	L. A. Jackson
Virginia	W. B. Harman	Brent Remsburg	J. B. Ferguson	E. H. Ruehl
West Virginia	D. H. Clark	H. K. Gidley	Edward Shroyer	H. W. Hetzer
Wisconsin	O. J. Muegge	P. S. Davy	E. W. Becker	Harry Breimeister

Directors Representing the Water and Sewage Works Manufacturers Assn.

J. A. Frank H. S. Howe R. V. Ford

Officers of the Divisions

Division	*Chairman*	*Vice-Chairman*	*Secretary*
Water Distribution	B. E. Payne	H. J. Graeser Jr.	J. G. Carns
Water Purification	C. A. Black	H. E. Hudson Jr.	J. M. Sanchis
Water Resources	A. R. Davis	R. W. Morse	L. M. Miller
Water Works Management	W. R. Seeger	Gerald Remus	C. W. Wilson



Growth of U.S. Population in Millions:

1900—75; 1950—150; 1990—300 (Estimated)

And proportionate demands on water and sanitary facilities are increasing even more rapidly because of industry's ever-growing need for water supply and waste disposal.

Over the past half century Lock Joint Pipe Company has helped keep pace with the requirements of a doubling population by supplying millions of feet of concrete pipe for vital water and sewer lines. Virtually 100% of these are still in service and are operating with the same high efficiency as the day they were installed.

This unexcelled record for economy, efficiency and safety certainly recommends Lock Joint Concrete Pressure and Sewer Pipe as the ideal material to implement the long range plans of water and sanitation officials to meet the growing crisis.

LOCK JOINT PIPE CO.

East Orange, New Jersey

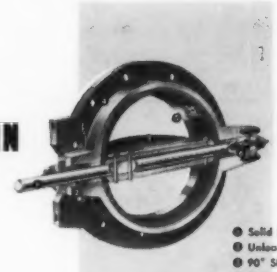
Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col.
Detroit, Mich. • Hartford, Conn. • Kansas City, Mo. • Perryman, Md. • St. Paul, Minn.
Pressure • Water • Sewer • **REINFORCED CONCRETE PIPE** • Culvert • Subaqueous

LIST OF ADVERTISERS

	P&R PAGE
Alabama Pipe Co.	47
Allied Chemical Corp., General Chemical Div.	—
Allied Chemical Corp., Plastics & Coal Chemicals Div.	—
Allis-Chalmers Mfg. Co.	11
Allis-Chalmers Mfg. Co., Hydraulic Div.	—
American Agricultural Chemical Co.	52
American Brass Co., The	—
American Cast Iron Pipe Co.	95
American Concrete Pressure Pipe Assn.	20, 21
American Cyanamid Co., Process Chemicals Dept.	22
American Hard Rubber Co.	—
American Pipe & Construction Co.	41
American Well Works	—
Andrich Water Specialty Co.	96
Anthracite Equipment Corp.	—
Aqua Survey & Instrument Co.	86
Armco Drainage & Metal Products, Inc.	61
Badger Meter Mfg. Co.	—
Bethlehem Steel Co.	10
B-I-F Industries, Inc.	5
Buffalo Meter Co.	—
Burgess-Manning Co., Penn Instruments Div.	—
Calgon Co.	—
Calmet Meter Div., Worthington Corp.	51
Carborundum Co., The	—
Carus Chemical Co.	—
Cast Iron Pipe Research Assn., The	26, 27
Centriline Corp.	—
Chain Belt Co.	—
Chapman Valve Mfg. Co.	—
Chicago Bridge & Iron Co.	—
Clow, James B., & Sons	7, 66, 67
Cochrane Corp.	—
Combination Pump Valve Co.	85
Darley, W. S., & Co.	44
Darling Valve & Mfg. Co.	—
De Laval Steam Turbine Co.	—
DeZurik Corp.	—
Dicalite Div.	—
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	87
Eddy Valve Co.	7, 66, 67
Electro Rust-Proofing Corp.	—
Ellis & Ford Mfg. Co.	—
Emhart Mfg. Co., Maxim Div.	—
Fairchild Aerial Surveys, Inc.	—
Fiese & Firstenberger	—
Filtration Equipment Corp.	94
Fischer & Porter Co.	17
Flintkote Co., The, Orangeburg Div.	—
Ford Meter Box Co., The	99
Foxboro Co.	24
Gamon Meter Div., Worthington Corp.	39
General Chemical Div., Allied Chemical Corp.	—
General Filter Co.	65
Glenfield & Kennedy	—
Golden-Anderson Valve Specialty Co.	79
Graver Tank & Mfg. Co.	43
Graver Water Conditioning Co.	—
Greenberg's, M., Sons	—
Griffin Wheel Co.	101
Hagan Chemicals & Controls, Inc.	—
Halliburton Oil Well Cementing Co.	63
Harco Corp.	—
Hays Mfg. Co.	48
Hersey-Sparling Meter Co.	23
Hungerford & Terry, Inc.	84
Ideal Electric & Mfg. Co.	—
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	33
Inertol Co., Inc.	45
Infilco Inc.	37
International Salt Co., Inc.	—
Iowa Valve Co.	7, 66, 67
Johns-Manville Corp.	15, Cover 4
Jones Chemicals, Inc.	—
Keasbey & Mattison Co.	12
Kennedy Valve Mfg. Co., The	—
Klett Mfg. Co.	88
Koppers Co., Inc.	89
LaMotte Chemical Products Co.	—
Layne & Bowler, Inc.	13
Leopold, F. B., Co.	16
Lock Joint Pipe Co.	3
Ludlow Valve Mfg. Co.	—
M & H Valve & Fittings Co.	19
Monterey Sand Co.	46
Morgan Steel Products, Inc.	83
Mueller Co.	29
Nalco Chemical Co.	9
National Tank Maintenance Corp.	44
National Water Main Cleaning Co.	103
Neptune Meter Co.	34
Northern Gravel Co.	92
Olin Mathieson Chemical Corp.	71
Orangeburg Mfg. Co., Div. of The Flintkote Co.	—
Peerless Pump Div.	—
Pelton Div., Baldwin-Lima-Hamilton	—
Permutit Co.	90, 91
Philadelphia Quartz Co.	—
Photovolt Corp.	77
Pilot Mfg. Co.	—
Pittsburgh-Des Moines Steel Co.	53
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	104
Plastics & Coal Chemicals Div., Allied Chemical Corp.	—
Pollard, Jos. G., Co., Inc.	31
Portland Cement Assn.	—
Pratt, Henry, Co.	—
Precision Chemical Pump Corp.	—
Preload Co., Inc.	—
Reilly Tar & Chemical Corp.	28
Roberts Filter Mfg. Co.	97
Rockwell Mfg. Co.	104
Rohm & Haas Co.	—
Ronald Press Co.	—
Ross Valve Mfg. Co.	14
Servicised Products Corp.	81
Shell Chemical Corp.	—
Simplex Valve & Meter Co.	49
Smith, A. P., Mfg. Co., The	93
Southern Pipe Div. of U.S. Industries	—
Steel Plate Fabricators Assn.	18, 73
Stuart Corp.	80
Taylor Iron Works	70
Tennessee Corp.	25
Trinity Valley Iron & Steel Co.	—
U.S. Pipe & Foundry Co.	—
Vulcan Materials Co.	—
Wachs, E. H., Co.	—
Walker Process Equipment, Inc.	69
Wallace & Tiernan Inc.	32
Wheeler, C. H., Mfg. Co.	75
Wiley, John, & Sons, Inc.	—
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	—
Worthington Corp	—

Directory of Professional Services—pp. *54-60 P&R*

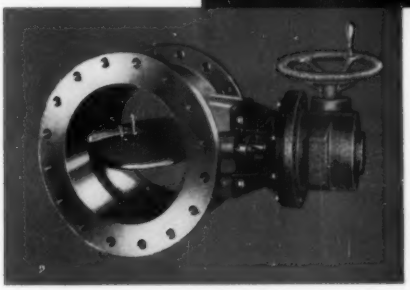
POSITIVE CONTROL OF MATERIALS IN MOTION B-I-F METERS FEEDERS CONTROLS

BUILT-IN  VALVE DEPENDABILITY...

- Solid Stainless Steel Shaft
- Unloaded Stuffing Box
- 90° Shaft Rotation
- Rugged Valve Body
- Unique Reinforced Valve Seat
- Two-Way Thrust Bearing

B-I-F Builders-Providence BUTTERFLY VALVES!

• NO "FREEZING"! • NO LEAKING! • MUCH LESS MAINTENANCE!



Performance-proved in the 25 to 125 psi range, Builders Butterfly Valves are built to AWWA specifications. Non-corrosive metal to rubber seating results in bubble tight closure and free and easy operation even after long periods of inactivity. Shaft rotates only 90° . . . reduces wear and tear on shaft and stuffing box. All types of valve operators available to suit your requirements.

B-I-F Industries

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

Ask for proof! Request Bulletins 650.20-1 & 650.20-2 for complete design details. Write to **B-I-F Industries, Inc., 365 Harris Avenue, Providence, R. I.**

AWWA ANNUAL CONFERENCE

Bal Harbour, Fla. May 15–20, 1960

Official reservation forms recently mailed to all members are returnable to AWWA postmarked on or after (but not before) noon, Feb. 8.

Coming Meetings

AWWA SECTIONS

Winter-Spring 1960

Jan. 26—New York Section, Midwinter Luncheon Meeting, at Park Sheraton Hotel, New York. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City 1.

Feb. 3–5—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, C. H. Canham, State Board of Health, 1330 W. Michigan St., Indianapolis.

Feb. 10—New Jersey Section, Winter Luncheon Meeting at Hotel Essex House, Newark. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Mar. 16–18—Illinois Section, at Pick-Congress Hotel, Chicago. Secretary, D. W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Mar. 17—New England Section, at Statler Hotel, Boston, Mass. Secretary, R. M. Soule, Assoc. San. Engr., State Dept. of Public Health, 511 State House, Boston, Mass.

Mar. 20–23—Southeastern Section, at De Soto Hotel, Savannah, Ga. Secretary, N. M. de Jarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta, Ga.

Mar. 24–25—West Virginia Section, at Hotel Pritchard (tentative), Huntington. Secretary, H. W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

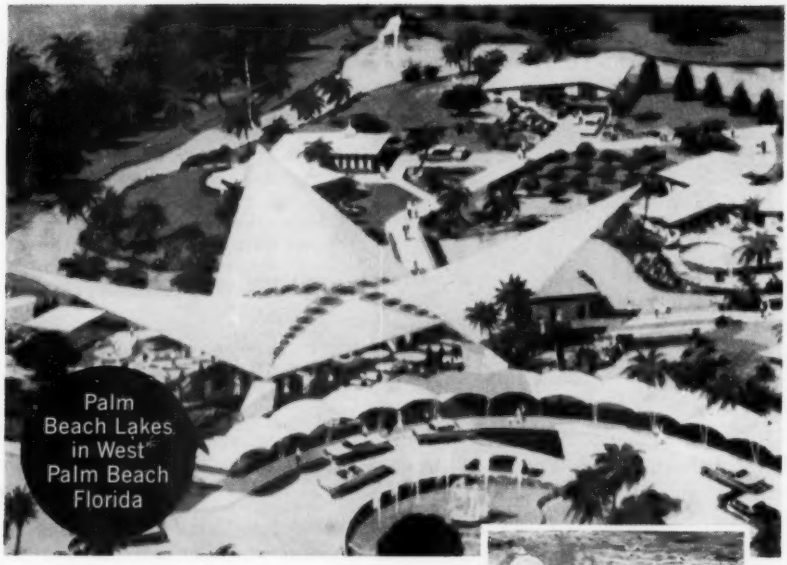
Apr. 5–7—New York Section, at New York Sheraton-Binghamton, Binghamton. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City.

Apr. 20–22—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, J. J. Rossbach Jr., Civ. Engr., Metropolitan Utilities Dist., 3906 N. 48th St., Omaha.

Apr. 20–22—Kansas Section, at Broadview Hotel, Emporia. Secretary, H. W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 22—California Section, at Mark Thomas Inn, Monterey. Secretary, R. E. Dodson Jr., Supt. of Water, Dept. of Utilities, Balboa Park, San Diego.

(Continued on page 8)



Uses hundreds of

IOWA FIRE HYDRANTS and GATE VALVES

IOWA Fire Hydrants and Gate Valves form an important part of the more than $4,000,000 investment in water and sewage facilities for a completely new "City Within a City", a Perini-Westward development, entirely within the city limits of West Palm Beach, Florida. One of the owners is Louis R. Perini, Chairman of the Board of the Milwaukee Braves and President of Perini Corporation.

The eye-catching central pavilion dominates a 12-acre exhibit in the nine-square-mile area where more than 40,000 people are expected to live. Hundreds of Iowa valves and hydrants were installed to control the flow of water and provide fire protection throughout the 100 miles of cast iron water mains serving this $450,000,000 development.

The IOWA products were selected because of their proved long life and easy maintenance... plus the assurance that parts and replacements will be always available. Such longtime future service is an important part of every purchase of IOWA products.

One of hundreds of IOWA fire hydrants and gate valves being installed at Perini-Westward development within the city limits of West Palm Beach, Fla.

Let us send you details on IOWA's *complete line of valves and hydrants*

IOWA VALVE COMPANY

Oskaloosa, Iowa

A subsidiary of James B. Clow & Sons, Inc.

Coming Meetings

(Continued from page 6)

Apr. 24–27—Canadian Section, at Statler Hotel, Buffalo, N.Y. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Apr. 28–30—Arizona Section, at Pioneer Hotel, Tucson. Secretary, A. D. Cox Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

Apr. 28–30—Montana Section, at Northern Hotel, Billings. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

May 4–6—Pacific Northwest Section, at Benson Hotel, Portland, Ore. Secretary, F. D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

Jun. 14–17—Pennsylvania Section, at Hilton Hotel, Pittsburgh. Secretary, L. S. Morgan, 413 First National Bank Bldg., Greensburg.

Fall 1960

Sep. 12–14—Kentucky-Tennessee Sec., Knoxville, Tenn.

Sep. 14–16—Virginia Sec., Virginia Beach.

Sep. 21–23—Michigan Sec., Traverse City.

Sep. 21–23—North Central Sec., Sioux Falls, S.D.

Sep. 25–27—Missouri Sec., Jefferson City.

Sep. 28–30—Wisconsin Sec., Madison.

Sep. 28–30—New York Sec., Whiteface.

Oct. 9–12—Alabama-Mississippi Sec., Birmingham, Ala.

Oct. 16–19—Southwest Sec., Galveston, Tex.

Oct. 19–21—Iowa Sec., Des Moines.

Oct. 19–21—Chesapeake Sec., Washington, D.C.

Oct. 20–22—New Jersey Sec., Atlantic City.

Oct. 23–26—Rocky Mountain Sec., Colorado Springs, Colo.

Oct. 24–27—California Sec., Long Beach.

Oct. 26–28—Ohio Sec., Columbus.

Nov. 9–11—North Carolina Sec., Winston-Salem.

OTHER ORGANIZATIONS

Jan. 25–29—Course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Jan. 27–28—2nd Sanitary Engineering Conference, University of Illinois, Urbana, Ill., cosponsored by the State Department of Public Health and the university's Department of Civil Engineering. Subject of the conference is "Radiological Health Aspects of Water Supply." Write: William J. Downer, Asst. Chief. San. Engr., Dept. of Public Health, Springfield, Ill.

Jan. 31–Feb. 5—AIEE, New York, N.Y.

Feb. 1–5—ASTM Committee Week, Sherman Hotel, Chicago, Ill.

Feb. 14–18—American Institute of Mining, Metallurgical & Petroleum Engineers, Hotel Statler, New York, N.Y.

Mar. 14–18—National Assn. of Corrosion Engineers Annual Convention, Memorial Auditorium, Dallas, Tex.

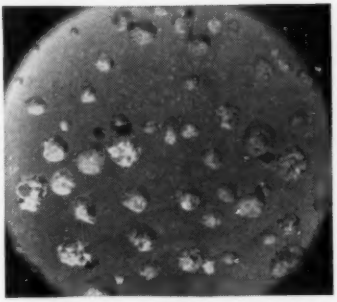
Mar. 16–18—23rd Short Course for Superintendents and Operators of Water and Sewerage Systems, Louisiana State University, Baton Rouge, La. Write: Fred H. Fenn, Dean, College of Engineering, at the university.

Apr. 3–8—6th Nuclear Congress, Coliseum, New York, N.Y., sponsored by EJC and other engineering and scientific societies, including AWWA.

New Coagulant Cuts Costs of Water Treatment

Fast Action Permits High Flow Rates

High speed coagulant action of Nalco 614 is especially good news for the many municipal water treating plants now operating over rated capacity. In fact, the extremely fast action of this new coagulant promises better operating efficiency in *any* municipal system.



Photomicrograph of Nalco 614 particles shows one of the reasons for its excellent handling and dry feeding characteristics: spherical grains that assure free flow through conventional dry feeders.

Characteristics of Nalco 614

Basically, Nalco 614 is a new sodium aluminate coagulant. It has excellent dry feeding characteristics due to a new manufacturing process that produces near spherical granules. It is a fast dissolving, highly soluble material.

Rapid coagulating action boosts equipment capacities, virtually eliminates post-precipitation.

Nalco 614 is being used alone, with lime and soda ash, and with low dosages of common coagulants such as alum or activated silica.

In softening systems, Nalco 614 improves hardness reduction, as well as coagulation. Since it is an alkaline material, lime and soda ash dosages can be reduced.

Plant Reports

There is no substitute for full-scale use of a new product to prove its usefulness and advantages. Here are some of the results that water works report after putting Nalco 614 to work:

"Saved almost $1,000 per Month over the cost of previous treatment, principally alum," says one filtration plant superintendent.

Replaced Alum and Ferric Sulfate at a municipal water plant in Iowa. This plant softens water to 85 ppm. Previous cost of alum, iron, lime and soda ash was $239.00 per day. Replaced 25 parts alum and 50 parts ferric sulfate with only 8 parts Nalco 614. Lime and soda ash dosages also reduced because of 614 alkalinity. Cut overall chemical cost to $150.00 per day; a saving of $89.00 per day — $32,485.00 per year!

1 ppm 614 Outperformed 10 ppm Alum according to the experience in a California municipal plant: "Nalco 614 is doing a beautiful job of both coagulation and feeding."

Quotes on Nalco 614 Handling

Here are some typical comments on Nalco 614 handling characteristics:

"I have never seen any material which fed as well and as uniformly as Nalco 614."

"Nalco 614 flows easily, requiring no agitation and no banging on the outside of the hopper."

"It feeds as easy as rice alum. We have been able to whip all of the feeding problems that have plagued us..."

Action for Your Plant

Nalco 614 has a record of results in municipal water treating that comes close to the spectacular . . . and there is no reason why it cannot perform the same way for you. Call your Nalco Representative, or write Nalco direct for prompt action toward Nalco 614 savings and performance in your plant.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY

nalco ®6216 West 66th Place • Chicago 38, Illinois

Affiliated Companies in Canada, Venezuela, Italy, Spain, West Germany

. . . Serving Industry through Practical Applied Science

Nalco CHEMICALS

Can you afford not to install steel mains?

Can you afford the damage to streets, the cost of flooded basements, the losses due to interrupted service should mains of other materials fail?

That's why you should use *steel* pipe—it's the strongest made. It withstands the highest pressures, it resists shock, vibration, explosions, earth tremors, freezing temperatures. It spans washouts. Have you ever heard of a *steel* main breaking?

Large-diameter steel pipe is protected from corrosion by advanced types of coal-tar enamel coating and lining materials. You'll get maximum flow capacity *indefinitely*.

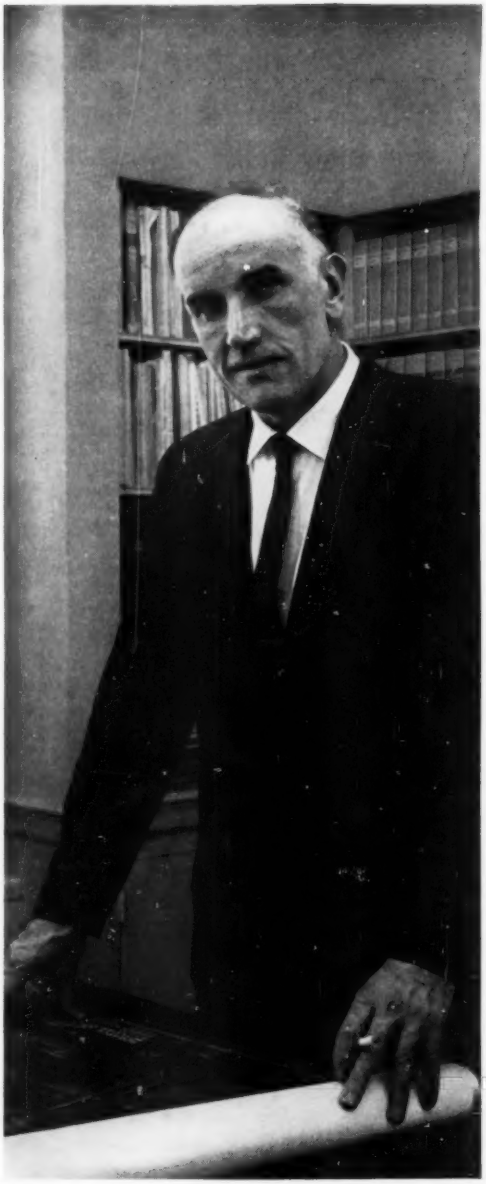
What's more, every length is hydrostatically tested in our shop to AWWA standards, usually to twice the design working pressure.

Can you afford *not* to use tar-enameled steel pipe for your transmission mains? Our nearest sales office will gladly give you complete information.

BETHLEHEM STEEL CO.
BETHLEHEM, PA.
Export Distributor:
Bethlehem Steel Export Corporation

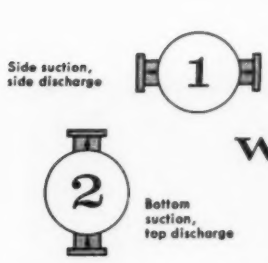
BETHLEHEM STEEL

BETHLEHEM STEEL



Pinched for pump space?

Make the most of it with an Allis-Chalmers centrifugal pump



Let the world's broadest centrifugal pump line lead you out of your installation space squeeze. Here's versatility that blankets every suction or discharge requirement — with horizontal (see 1 to 4 illustrated) or vertical (see 5 and 6) mountings. Capacities run from a flow to a flood — to 250,000 gpm or more.

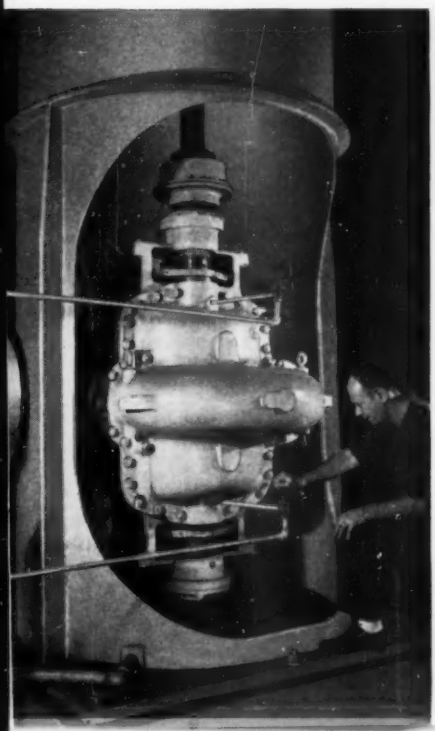
The size of the A-C pump line, the service and experience behind it, are without equal in industry. For data, contact your A-C representative or distributor. Or write to Allis-Chalmers, General Products Division, Milwaukee 1, Wis.

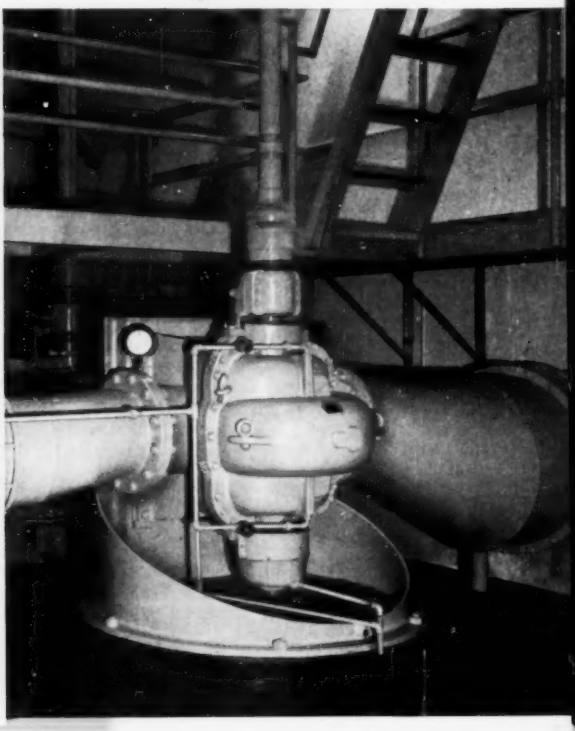
ALLIS-CHALMERS

A-1197-JAW

Vertical mounting with barrel supporting motor provides for discharge at either 90° to the suction (shown at lower left) or at 180° to the suction.

Mounted vertically, Allis-Chalmers pumps can be driven with motor on another floor — discharge at either 180° to the suction (shown at lower right) or at 90° to the suction.





"it's true; now "K&M" offers one-stop shopping for both asbestos-cement and plastic pipe!"

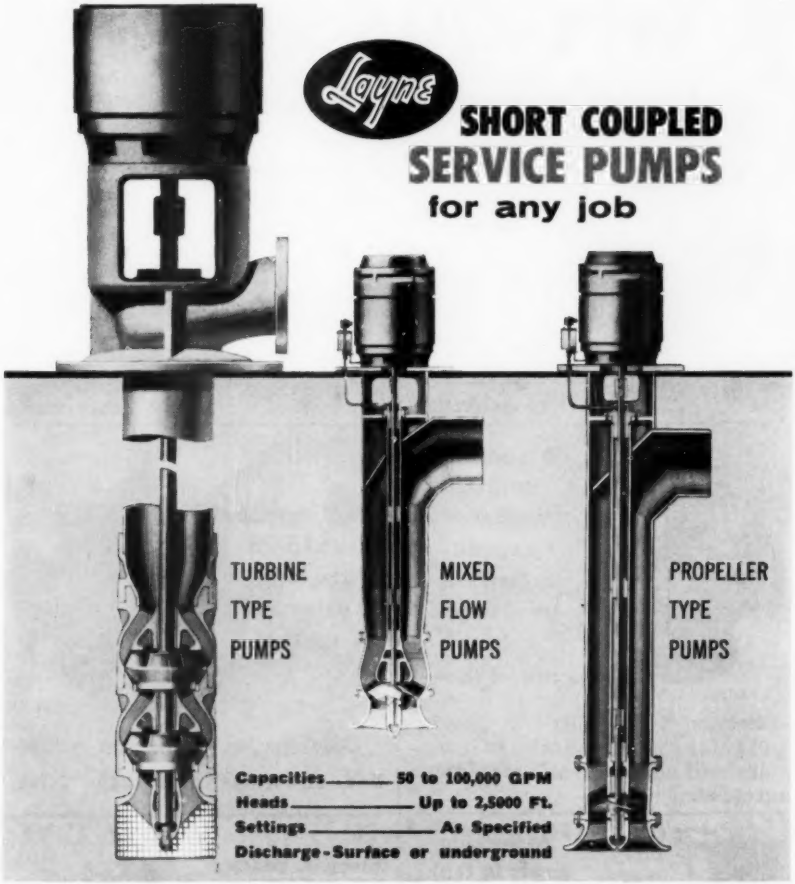
"K&M" adds 4 types of plastic pipe to its quality line of Asbestos-Cement Pipe! No need any more to buy quality Asbestos-Cement Pipe from "K&M" . . . and then expend time and energy shopping for Plastic Pipe elsewhere. Now, it's as easy as shopping in a supermarket! Get both types of pipe from the source you've always been able to rely on: "K&M"! But, that's not all! You can also simplify planning by fitting both "K&M" Asbestos-Cement and "K&M" Plastic Pipe into the same system . . . custom-tailoring it to your design and your budget requirements. You can get tough, thrifty "K&M" Plastic Pipe at all "K&M" factory locations. Plus a complete line of "K&M" Plastic Pipe Fittings.

K·M
BEST IN ASBESTOS

KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

Write today for these informative and illustrated brochures . . . packed with facts on each type of new "K&M" Plastic Pipe!

"K&M" Polyethylene Pipe • "K&M" Normal-Impact Polyvinyl Chloride Pipe • "K&M" Acrylonitrile Butadiene Styrene Pipe • "K&M" High-Impact Styrene-Alloy Sewer Pipe



Top performance, high efficiency and less maintenance are factors which influence the selection of a short coupled pump. Layne Vertical Service Pumps fulfiill these requirements and offer the advantages of lower installation and operation costs, low submergence requirements, simple alignment, no priming and less floor space demands. For any short coupled pumping job . . . specify Layne.

Write For Free Bulletins:
LAYNE TURBINE TYPE SERVICE PUMPS—NO. 300
LAYNE PROPELLER AND MIXED FLOW PUMPS—NO. 350

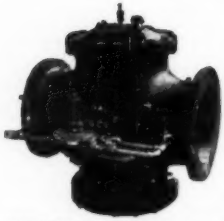
World's Largest Layne Water Developers

LAYNE & BOWLER, INC., MEMPHIS
General Offices and Factory, Memphis 8, Tenn.
LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD
SALES REPRESENTATIVES IN MAJOR CITIES

Water Wells • Vertical Turbine Pumps • Water Treatment

1879—ROSS—1879

Automatic Valves

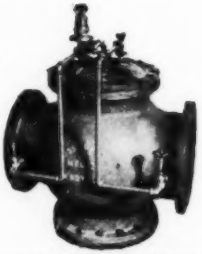


ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge



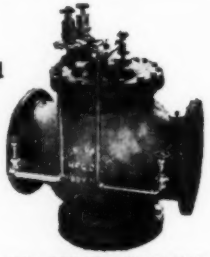
SURGE-RELIEF VALVE

REDUCING VALVE

Maintains desired discharge pressure regardless of change in rate of flow

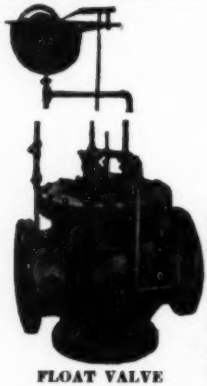
Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls



COMBINATION VALVE

Combination automatic control both directions through the valve.

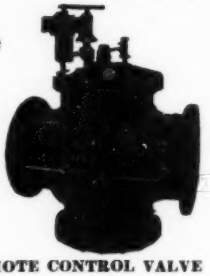


FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

Electric remote control—solenoid or motor can be furnished



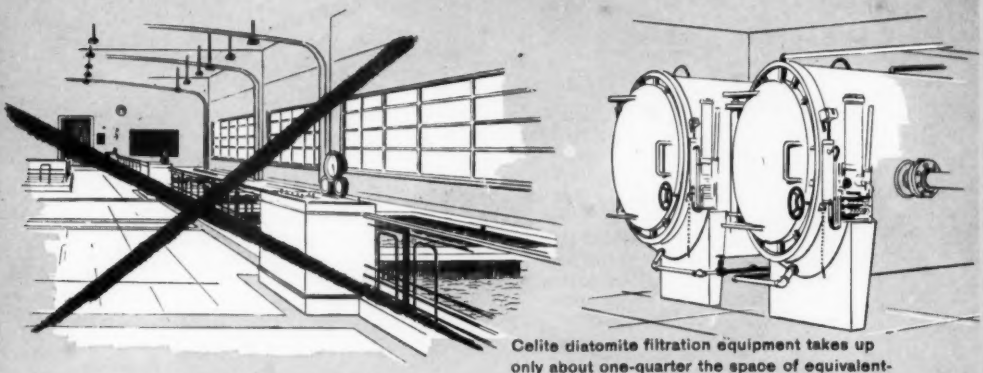
REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N. Y.

1. REDUCE FILTER HOUSING SPACE 75%



Celite diatomite filtration equipment takes up only about one-quarter the space of equivalent-capacity sand filter systems.

2. USE LOWER-COST CONSTRUCTION

Smaller floor space needed for diatomite filtration permits lighter, lower-cost building methods and materials.

You save filtration construction dollars these 2 ways with Celite diatomite

One installation after another proves you need about 75% less filter housing space for equivalent capacity when you use diatomite filtration with Johns-Manville Celite*.

Also, diatomite's lighter, smaller equipment permits you to use lower cost building methods and materials. For example, a simple concrete slab with light framing and siding instead of a large reinforced concrete-and-brick building with built-in concrete filters#.

Diatomite filter equipment is so compact because it provides a much larger filter surface in proportion to size of equipment. In many cases, raw water can be filtered directly—pretreatment facilities can be eliminated. For Celite removes more suspended solids, including amoebae and algae, and turbidity is usually much lower.

Mined by Johns-Manville from the world's largest and purest commercial diatomite deposit, Celite is carefully processed for purity and uniformity. It is available in a wide range of grades for best practical balance of clarity and flow rate with any suitable filter. For further information, see your nearby Celite engineer. For free technical reprints and illustrated brochure, write to Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.

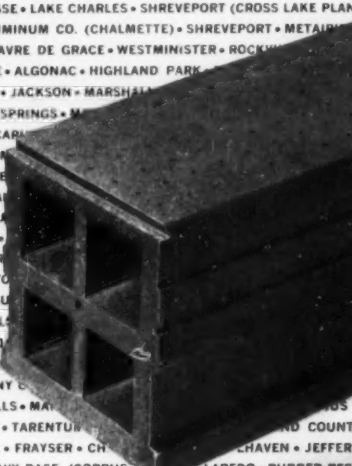
JM PRODUCTS

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

#*See Comparison Studies of Diatomite and Sand Filtration* by G. R. Bell, Journal American Water Works Association, September, 1956 or write for free reprint.

JOHNS-MANVILLE

FORT LAUDERDALE • ST. PETERSBURG • FORT MYERS • NAPLES • GAINESVILLE • "MARINELAND" (ST. AUGUSTINE)
WEST POINT • MARION • JACKSONVILLE • EVANSTON • MOLINE • GRANITE CITY • VANDALIA • MATTOON • ALTON • FR
STREATOR • EAST ST. LOUIS • WILLIAMSON COUNTY • INDIANAPOLIS • BEDFORD • GENERAL MOTORS (INDIANAPOL
RICHMOND • COUNCIL BLUFFS • CENTERVILLE • DAVENPORT • DUBUQUE • CRESTON • HUMESION • WEST DES MOINE
OSAGE CITY • BELOIT • GRENOLA • KANSAS CITY • ATCHISON • ELLSWORTH • MANHATTAN • HAYS • TOPEKA • OLAT
WICHITA • ALTAMONT • LAWRENCE • MORRIS • ST. PAUL • FT. SCOTT • EUREKA • DESOTO • LAWRENCE • RUBBER RES
PRINCETON • OWENSBORO • HOPKINSVILLE • LEXINGTON • U.S. ARMY (FORT CAMPBELL) • JEFFERSON COUNTY •
BELLE CHASSE • LAKE CHARLES • SHREVEPORT (CROSS LAKE PLANT) • ALEXANDRIA • EMPIRE • KAISER ALUMINUM
KAISER ALUMINUM CO. (CHALMETTE) • SHREVEPORT • METAIRIE • MARRERO • LOGANSPORT
BEL AIR • HAVRE DE GRACE • WESTMINISTER • ROCKVILLE • YPSILANTI • FILER
WYANDOTTE • ALGONAC • HIGHLAND PARK • FAIRMONT
VICKSBURG • JACKSON • MARSHALL • PLA
EXCELSIOR SPRINGS • RICHMOND •
IRONTON • CARL • GREAT FALLS •
LINCOLN • OR • ROCTON • TON
FREDONIA • E • NFORD • LILLI
CORNING • AL • FIN • AVON LA
WINDHAM • J • ON • ELYRIA •
McALESTER • ORE • DURANT
WILKINSBUR • R HOME (EVA
FREDERICKTO • NALD • ALIQUI
READING • GU • LOOMSBURG •
CARMICHAELS • EASURE ISLAND POOL,
HILLMAN CO • UNION CITY • CHARLEROI • BI
NEW KENSI • SHARPSVILLE • MONONGAHELA • HA
LETTERKENNY • NGTON • LEWISTOWN • NEW CASTLE • ELIZA
BEAVER FALLS • MA • HOOK) • QUARRYVILLE • BRECKENRIDGE • RED
EVANS CITY • TARENTU • ND COUNTY • EDGEFIELD • WALHALLA • MOBRIDGE • CLARK
SEVIERVILLE • FRAYSER • CH • CHAVEN • JEFFERSON CITY • SEWANEE • HARRIMAN • HUNTINGD
BORGER • NAVY BASE, (CORPUS • , • LAREDO • RUBBER RESERVE CORP., (BORGER) • SYNTHETIC RUBBER P
PHARR • MONTE ALTO • BROWNSVILLE • DONNA • SAN ANGELO • BEAUMONT • FORT WORTH • LLANA • MARSHALL • N
ELECTRA • SWEETWATER • WICHITA FALLS • WESLACO • BAIRD • IOWA PARK • ABILENE • PORT ARTHUR • SAN BEN
HOUSTON • STAMFORD • RIVER OAKS • WACO • RIO GRANDE CITY • GULF OIL CORP. (WEST PORT ARTHUR) • SP
EAGLE PASS • PHILLIPS CHEMICAL CO. (HOUSTON) • ALBANY • WEATHERFORD • INDUSTRIAL FILTER CO. (HOUSTO
IOWA PARK • NORFOLK • PORTSMOUTH • AMERICAN VISCOSE CORP. (FREDERICKSBURG) • AMERICAN VISCOSE
NEWPORT NEWS • WHEELING • MATEWAN • CHARLESTON • WEIRTON • AMHERST COAL CO. (LUNDSDALE) • MT. HO
MOOREFIELD • LOGAN • MONONGAH • RICHWOOD • FAIRMONT • KINGWOOD • NORTH FORK • PHILLIPI • NITRO • RIPLE
HANCOCK COUNTY • AMHERSTDALE • ALDERSON • HARRISVILLE • KERMIT • MILTON • STATE COLLEGE (LIBERTY) •
APPLETON • RACINE • LOVELL • WORLAND • CHEYENNE • JOLIETTE • VANCOUVER • CORNWALL • GRIMSBY • NIAGARA



These ~~464~~ 495 plants* know . . . the list keeps growing!

How to get to the bottom of backwash problems

The best way is to install Leopold Glazed Tile Filter Bottoms, just as all these plants have done.

Like them, you'll find Leopold Bottoms successfully meet all underdrain requirements. The individual Leopold blocks can't corrode or absorb water . . . are acid and alkali resistant . . . are not subject to tuberculation . . . and provide equal filtration and uniform wash distribution. In addition, because Leopold Bottoms won't wear out and assure minimum media maintenance, they are the most economical in the long run.

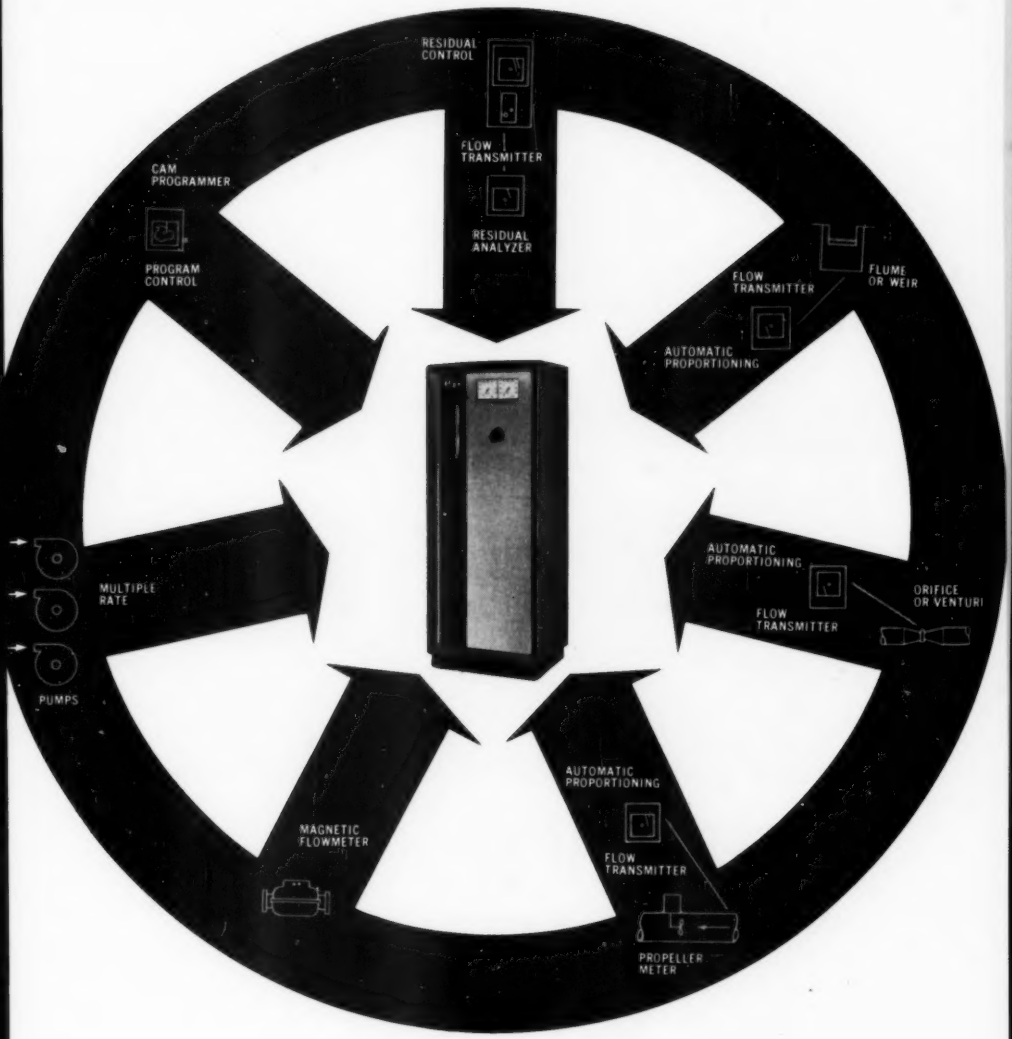
We'll be glad to supply facts and figures without obligation.

Including over 100 rehabilitation projects

F. B. LEOPOLD CO., INC.
ZELIENOPLE, PA.

Exclusive Canadian Representative: W. J. Westaway, Ltd., Hamilton, Ont.

Leopold



LECTRICALLY CONTROLLED CHLORINATION SYSTEMS

The commands are electric. The operation is omatic. Engineered by F & P . . . chlorination s modern.

Regulate chlorine feed rate *precisely, automatic-* with electrical signals from program controllers, ltiple and step rate controllers, automatic proportioning controllers, remote controllers, magnetic flowmeters, and residual analyzers. Don't invest in *any* chlorination system until you check out F & P Electrically Controlled Chlorination Systems. Fischer & Porter Company, 910 Fischer Road, Hatboro, Pennsylvania.

FISCHER & PORTER COMPANY *INSTRUMENTATION AND CHLORINATION*

MANUFACTURING AFFILIATES carry Fischer & Porter engineering designs to the far corners of the earth: FISCHER & PORTER LTD., WORKINGTON, CUMBERLAND, ENGLAND • FISCHER & PORTER G.m.b.H., GROSS-HAUSEN, BEI GOTTINGEN, GERMANY • FISCHER & PORTER N.V., KOMEETWEG 11, THE HAGUE, NETHERLANDS • FISCHER & PORTER Pty. LTD., 184 HANNA ST., SOUTH MELBOURNE, VICTORIA, AUSTRALIA.

STEEL PIPE IS RELIABLE AND RESILIENT

is your water supply safe from...

"Wherever water flows—steel pipes it best"

STEEL PLATE FABRICATORS ASSOCIATION

105 West Madison Street
Chicago 2, Illinois

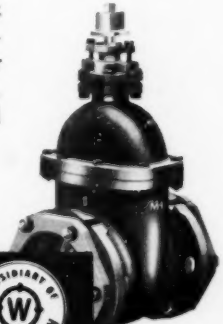
THE POPULATION BOMB

Economists and scientists refer to a rapid increase in the number of people as a "population explosion." U. S. population today is estimated at around 175 million and is increasing at the rate of about 7,500 each day—a new citizen every 12 seconds. Census experts expect U. S. population will be 250 million by the 1980's.

The basis of increased water use is an increase in consumers plus greater consumption per capita. U. S. is experiencing both. Total water use in the U. S. in 1900 was about 35 billion gpd. By 1950 it had increased to 200 billion, in 1959 it is 300 billion, and by 1975 it is expected to be well over 400 billion gpd.

A local water problem may involve insufficient quantity, poor quality and inadequate distribution. Federal, state and local officials and your water works superintendent know what to do. But they cannot do it without wholehearted public support.

This series is an attempt to put into words some appreciation of the water works men of the United States.



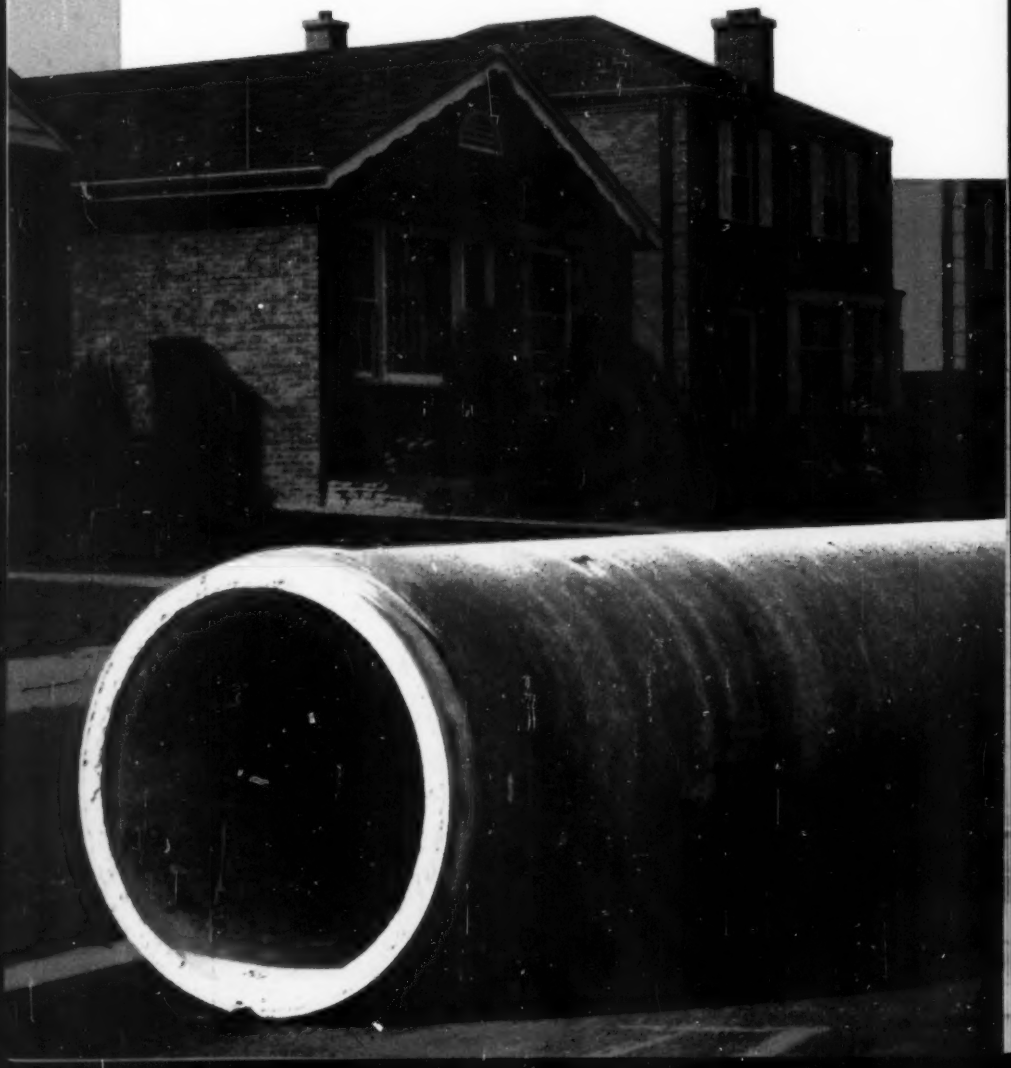
M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF WALWORTH

YOU'RE ON

EASY STREET

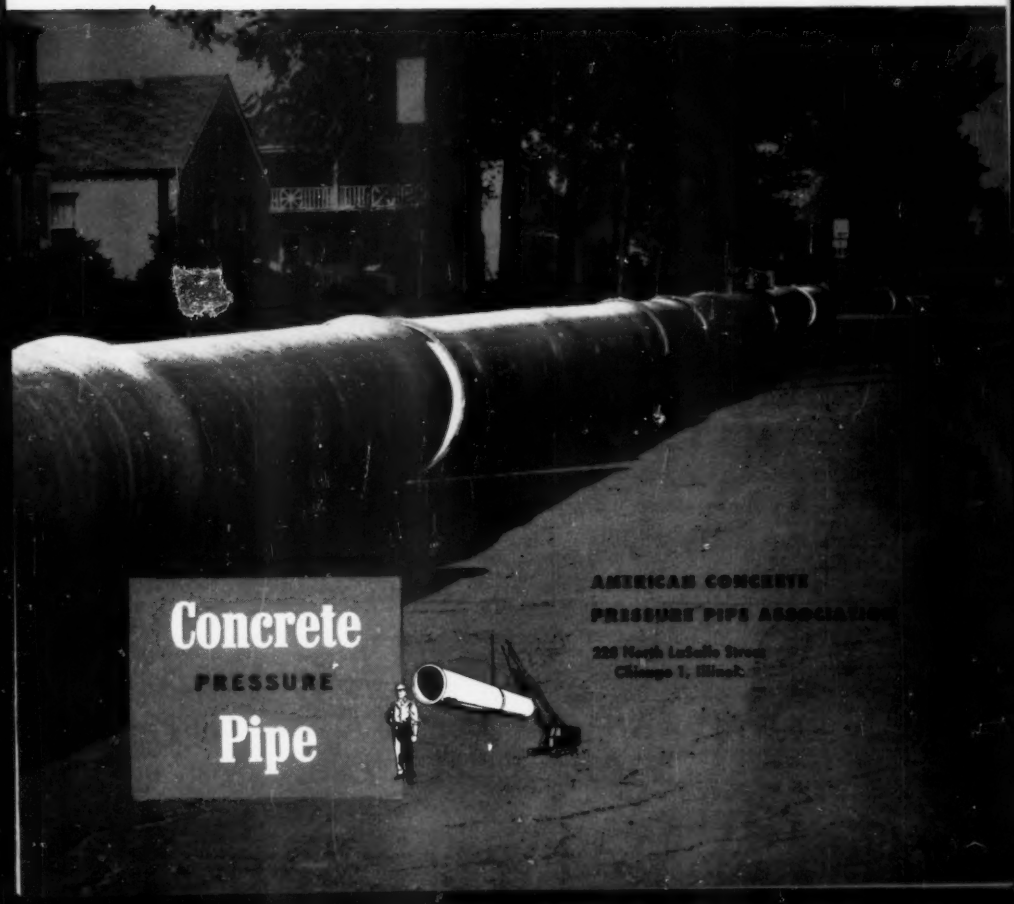
With Water Distribution Lines of
Dependable Concrete Cylinder Pressure Pipe

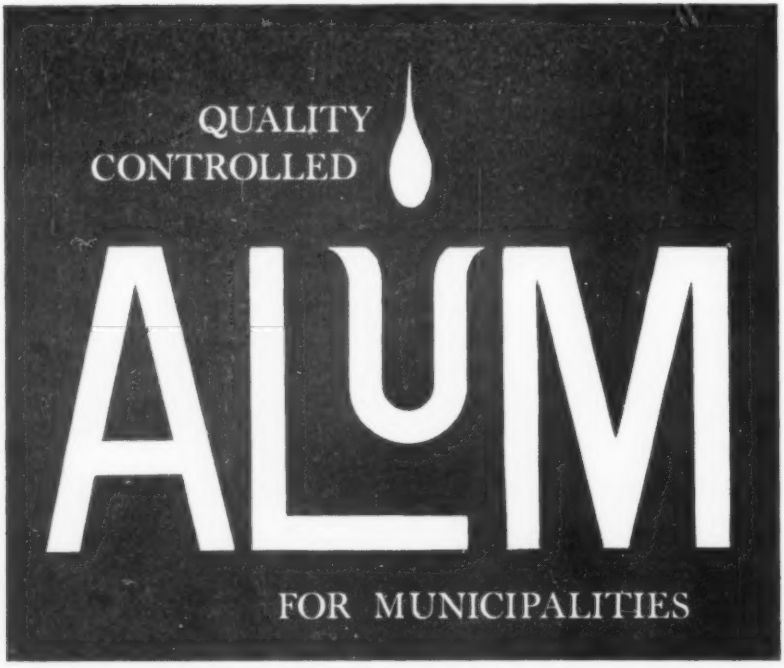


Concrete Cylinder Pressure Pipe has an unexcelled record for complete reliability. It is your community's best protection against the costly damage claims that can result from water line failure. It is also insurance against the expense and problems usually connected with the repair of water lines particularly in congested locations.

Further, Concrete Cylinder Pressure Pipe can be simply and efficiently tapped under pressure. This makes it easy to establish either service connections for an expanding community or cross connections with other lines in your water distribution system.

WATER FOR GENERATIONS TO COME





Cyanamid Alum is quality controlled from start to finish to meet stringent specifications. Manufacturing plants are strategically located for efficient service.

SUPPLIED IN THE FORM YOU WANT:

Liquid — for cleaner, easier, more economical operation. In tank wagons and tank cars from 9 convenient shipping points. Conforms fully to AWWA standards.

Dry — conforms fully to AWWA standards in ground, rice, lump or powdered grades. Bagged or bulk.

WHY NOT CONVERT TO LIQUID?

Your costs — and savings — can be determined quickly by a Cyanamid representative with years of conversion experience at your service. Just call Cyanamid for product or technical service of any kind.

CYANAMID

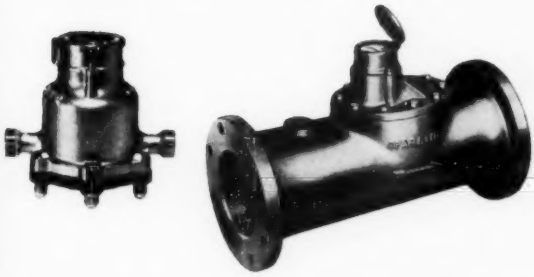
AMERICAN CYANAMID COMPANY

Process Chemicals Department, 30 Rockefeller Plaza, New York 20, N. Y.

In Canada: Cyanamid of Canada Limited, Montreal and Toronto

Announcing

A NEW NAME IN THE WORLD OF WATER METERS



On January 1, 1960 two of the oldest and best-known names in the field of water measuring equipment joined forces.

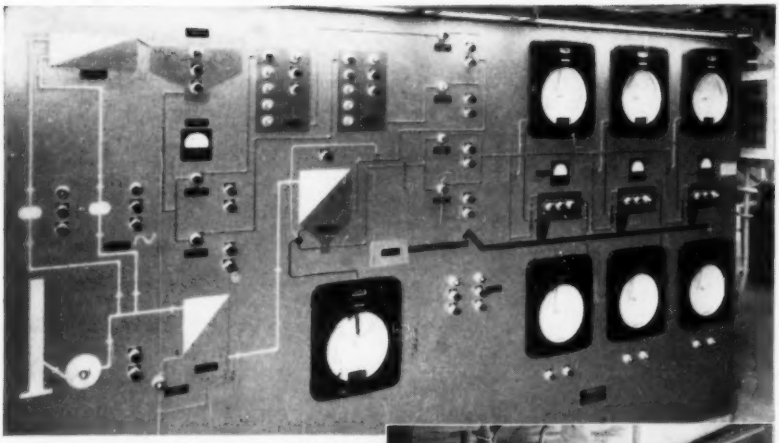
Hersey Manufacturing Company of Dedham, Mass., and Sparling Meter Company of El Monte, Calif., have merged under the name Hersey-Sparling Meter Company, with executive offices in Dedham, Massachusetts.

The new organization supplies meters ranging from small household models up to meters for pipe as large as 19 feet in diameter.

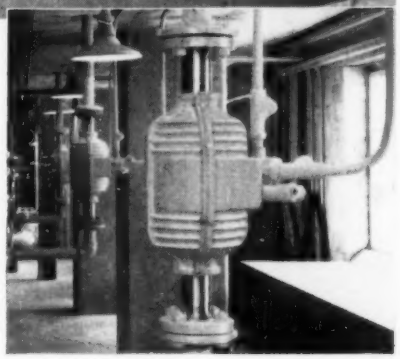
HERSEY-SPARLING METER COMPANY

DEDHAM, MASSACHUSETTS

● *Branches In Principal Cities*



Graphic control panel in Feed End Building of the $1,330,000 Dayton, Ohio Lime Recalcining Plant. *Consulting Engineers: Black & Associates, Gainesville, Florida.*



Three Foxboro Magnetic Flow Meters give continuous, accurate measurement for exact control and recording of sludge flow rate to centrifuges.

at City of Dayton–

self-amortizing lime recovery plant designed around Foxboro Magnetic Meters

Installed to recover lime used in softening city water, Dayton, Ohio's million-dollar Lime Recalcining Plant actually recovers up to 20% more lime than originally added; with additional capacity to process previous sludge accumulation. Capable of recovering 150 tons of lime per day, it is expected to amortize its original cost in 20 years — and pay a substantial surplus, too.

Dayton's efficient recalcining plant was designed around Foxboro Magnetic Flow Meters — which have no flow restrictions, and easily handle sludge that soon would foul-up conventional head-loss devices. They have no pressure taps or moving parts to foul . . . need no seals or purges. Maintenance is practically nil. Rate of flow to centrifuges can be controlled exactly.

For either "difficult" or "simple" liquids, Foxboro Magnetic Flow Meters are a sound investment. Ask your Foxboro Field Engineer, or write for Bulletin 20-14C. **The Foxboro Company, 161 Norfolk Street, Foxboro, Massachusetts.**

FOXBORO
REG. U.S. PAT. OFF.

MAGNETIC FLOW METERS

These new facilities now in operation at Copperhill, Tennessee substantially increase our production of Ferri-Floc and will permit us to supply the increased demands for this superior coagulant at all times.

THE COAGULANT WITH THE PLUS FEATURES

Ferri-Floc — Ferric Sulfate

Excellent Taste and Odor Control — *Turbidity Removal*
Increased Filter runs — *Manganese and Silical Removal*
Coagulation over Wide pH range — *Bacteria Removal*
Rapid Floc Formation — *Ease of Operation*
Efficient and Economical

AVAILABLE IN BULK, AND ALSO IN DOUBLE LINED POLYETHYLENE BAGS AT NO EXTRA COST.

FREE BOOKLET—We will send you, without charge, a 38 page booklet that deals specifically with all phases of coagulation—Just make request on your firm's letterhead.

TC TENNESSEE CORPORATION
615-629 GRANT BUILDING, ATLANTA 3, GEORGIA

IF YOUR DECISION MUST STAND UP FOR 100 YEARS

If your decision today will in some way determine your town's water supply system for the next century, consider the case for cast iron pipe:

- Cast iron pipe is built to *last*—96 American cities will testify to that. They've had cast iron pipe installations in constant use for over a century! And in Versailles, France, they're still using cast iron pipe water mains that were laid in 1664! Solid proof that once cast iron pipe is in the ground, it stays there!
- Cast iron pipe rarely requires repair. Its rugged construction, corrosion-resistant qualities and bottle-tight, rubber-ring joints will withstand the most severe pressures. Once an investment is made in cast iron pipe, it is usually your first and last cost because of the absence of maintenance or repairs.

Don't be fooled by initial pipe costs. You can't save money on "low-cost" pipe if you have to repair and replace it frequently. Insist on the pipe that will actually save you money over a period of years—cast iron pipe!

THE MARK OF THE 100-YEAR PIPE

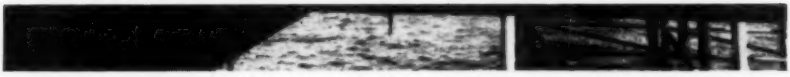
CAST IRON PIPE

Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, 3440 Prudential Plaza, Chicago 1, Illinois

FIRST

first off-shore sulphur production in the

world will move through Reilly-coated lines



Seven miles off Grand Isle, Louisiana, sulphur will be raised by the Freeport Sulphur Company from a mine 2,000 feet below the ocean floor. Reilly Hot Coal Tar Enamels—Hot Service Enamel with HS X-1 Primer—applied by Pipe Line Service Corporation—will protect delivery lines to shore installations against salt water and other corrosive elements. Inquire at any Reilly Sales Office.

REILLY TAR & CHEMICAL CORP

1615 MERCHANTS BANK BUILDING

INDIANAPOLIS 4, INDIANA

Reilly COAL TAR PRODUCTS

ARMED Protective Coatings

Sales offices in principal cities

fast installation in existing piping!

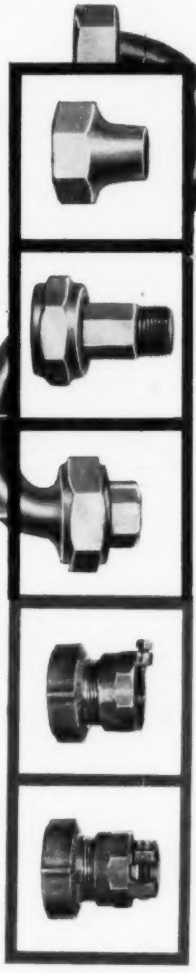
MUELLER®

COPPER METER YOKES

Now, compression couplings are available for Mueller Copper Meter Yokes with Multi-purpose Ends.

These new, time-saving couplings can be quickly stubbed into existing piping without cutting threads or sweating joints.

They can be furnished for steel or copper pipe in both the regular compression nut design or the locking nut design shown. The locking nut type positively prevents any movement of the yoke on the pipe and insures continuous electrical bonding of the service line.



Body Coupling Nut for copper pipe

Tailpiece with outside I.P. Thread

Combination Tailpiece with inside I.P. Thread for steel pipe and flared connection for copper pipe

NEW! Compression Coupling with locking nut for steel pipe (Regular nut available)

NEW! Compression Coupling with locking nut for copper pipe (Regular nut available)

Write for complete information and specifications.

MUELLER CO. since 1857 SERVING the Natural Gas Industry QUALITY

MUELLER CO.

DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles
In Canada: Mueller, Limited; Sarnia, Ontario

New AWWA

35-mm

Slide Film

with

Sound and

Color

$35 a copy

THE STORY OF WATER SUPPLY

Based on AWWA's million-copy bestselling picture booklet of the same name, the film version uses lively color cartoon slides and synchronized sound to tell "The Story of Water Supply" to schools, civic clubs, and other groups of your neighbors and customers. Attractive to both youngsters and adults, and easily understood by all, the effectiveness of this 15-minute presentation is being proved throughout the country.

Whether you use the film as an introduction to a talk on local water problems or lend it to your schools (a teaching guide comes with it), you're bound to find that its value as a public relations tool is worth far more than the modest $35 cost.

Order Now From

AMERICAN WATER WORKS ASSOCIATION

2 Park Avenue **New York 16, N.Y.**

M-Scope "Master" Electronic Witch
Leak Survey Instrument and Pipe Locator

The transistorized "MASTER" Leak Detector—Pipe Finder Combination is the first dual purpose instrument with separate and independent leak detector and pipe finder circuits. Now you can have two instruments in one without any compromise in performance. The "MASTER" Leak Detector—Pipe Finder incorporates the very latest advances in electronic construction and circuitry in addition to having an exceptionally long battery life. An ideal instrument for any Water Department.

Finding a leak under pavement

Locating a leak at the valve

Location of dead ends

Locating a service

Write for information, demonstration or trial.

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

PIPE LINE EQUIPMENT

Place your next order with POLLARD

If it's from POLLARD It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 964 Peoples Gas Building, Chicago Illinois
333 Candler Building, Atlanta, Georgia

There's no waste water from a V-notch

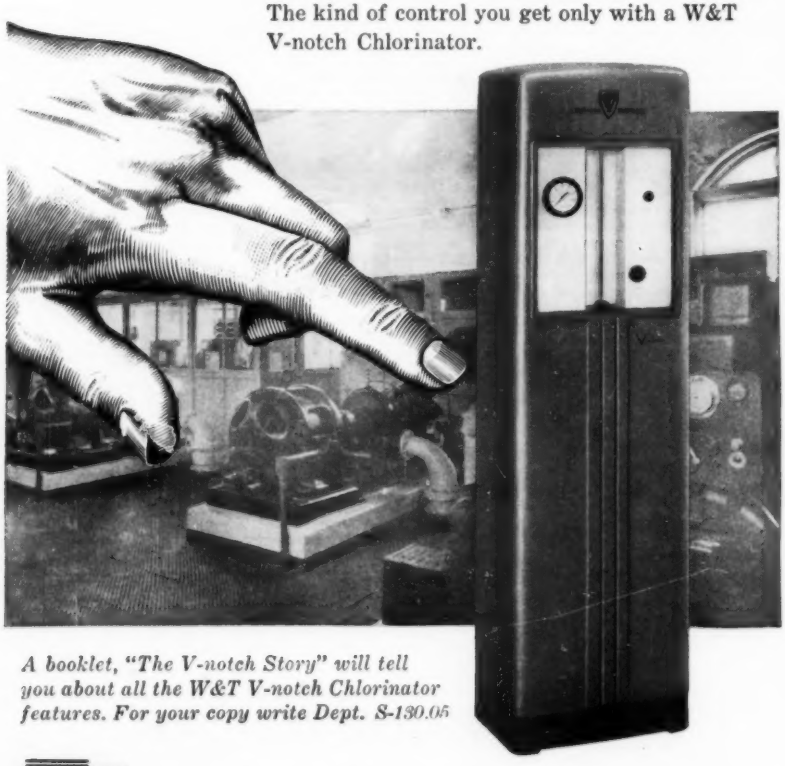
Why?

Because a V-notch Chlorinator needs no auxiliary water supply.

You can plan on clean, dry chlorinator rooms with no messy drain—no chlorine gassing back. And best of all... gone forever is the high cost of wasted auxiliary water.

And, of course, the right plastics make the whole chlorinator chlorine-proof.

Yet these are just added benefits to the main job: Simple, dependable, wide range chlorine control. The kind of control you get only with a W&T V-notch Chlorinator.



A booklet, "The V-notch Story" will tell you about all the W&T V-notch Chlorinator features. For your copy write Dept. S-130.05

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET. BELLEVILLE 9, NEW JERSEY

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 52 • JANUARY 1960 • NO. 1

Water Supply—America's Greatest Challenge

Lauren W. Grayson

A statement by Lauren W. Grayson, President, American Water Works Assn., based on an address delivered Jun. 5, 1959, at the annual convention of the General Federation of Women's Clubs, Los Angeles, Calif.

AN intrinsic part of our American character is the endless search for the "better way"—for a happier and more prosperous tomorrow.

One of the most priceless gifts that has been handed down to us from generation to generation is that individual American quality of never being satisfied with things as they are. We Americans are constantly looking for ways to improve our lives, our health, our jobs, our government, and the preservation of our natural resources. How else can you explain why we have been such a progressive and successful nation?

In the last 50 years our country has experienced the greatest change in its history. We have had, for example, a phenomenal growth in population. Since the turn of the century our population has doubled in size, and, looking ahead, we see a nation in 1975 of over 235,000,000. The growth of our cities, like the growth of many industries, has created numerous problems. Cities, especially those of 25,000 and over, are today facing problems that local governments never had to face before. True, we have entered the golden era of "pushbutton" luxuries in the home and in the industrial plant, but if we hold the mirror a little closer we can see ourselves also as a nation of shortages. *We are running out of facilities to take care of our skyrocketing population.*

In the face of our postwar prosperity, mobility, and population growth, we have been deficient in certain basic needs essential to the safety, health, comfort, and well-being of almost every community in the land. We have seen hospital facilities taxed beyond their capacity. We are just beginning to do something about an adequate highway system to take care of our 76,000,000 motorists. We are still short 228,000 classrooms in our public school system, although, thanks to the

vigilance of volunteer citizen committees, we are gradually getting off the double-sessions standard. And supply has yet to catch up with demand for low-cost housing. These are some of the problems we have all become familiar with during the past 10 years.

What has been the moving force in meeting these problems? Public understanding. What the public *does* depends upon what it *understands*. Action, therefore, is predicated upon attitude. It has always been my conviction that, once the American people are properly informed about a problem, its solution is assured. No better example can be found than the progress in meeting our school building shortage. But all the advances being made in such essential facilities as schools, hospitals, housing, and highways could be severely undermined unless we face up to another great challenge—water supply.

Facilities Needed

It isn't true, of course, that we are in grave danger of a water supply shortage. But we are in the midst of a critical shortage of water *facilities*. Frankly, we are not properly equipped to collect, store, process, and transport water in sufficient quantity and quality to meet the needs of our population.

In a recent survey,[1] *Fortune* magazine stated: "Apathy and the headlong rush to suburbia have made water and sewage facilities the greatest single deficiency in America's public works problems arising out of the postwar period of prosperity. And the way things are going, we may not catch up for 40 years."

The Business and Defense Services Administration estimates [1] that almost half of the people who use public water supplies can't be sure of having enough water available on a hot summer day to put out a major fire.

In towns of 25,000 and over, we are told by the Public Health Service [2]:

> One out of five water utilities is deficient in supply.
>
> One out of three water utilities is deficient in transmission capacity.
>
> Two out of five are deficient in treatment capacity.
>
> Nearly six out of ten require distribution system improvements.

This simply means we are getting our water from inadequate plants, in insufficient quantities, and at too low pressures for our home and industrial needs. And when this water does reach our faucets, though it is always safe to drink, its chemical and physical quality is often below the standard that water utility engineers would recommend.

What is the worst that can happen to a town's water supply?

Many will remember the severe drought between 1952 and 1957. The people in Chanute, Kan., will never forget it. Chanute was intermittently plagued by water shortages due to failure to provide adequate source facilities. Drastic measures were taken to conserve the existing water supply, but the situation reached disaster proportions when the Neosho River, the town's main source of supply, literally dried up.

With time running out, the town had to resort to a method of desperation—recirculation of treated sewage. Since water entered the town from upstream and sewage flowed downstream, a dam was hastily constructed to back up the polluted water. The water was then recirculated to the incoming water system. Engineers were able to make the water safe for drinking, although it

could not be made an acceptable-quality product.

Let me reemphasize that Chanute had literally no water supply. It had only a small plant for the treatment of used water. So the only alternative was to take water that had been used and stored in the polluted pool and process it for human consumption. Not very pleasant, but it does demonstrate what can happen in many communities across America.

Let's look a bit further into the local problem.

In 1953 over 1,000 public water supply systems restricted the use of water to part or all of their 24,000,000 consumers; 51 per cent of these ultilities experienced shortages as the result of population growth and increased seasonal use; 34 per cent, because of supply failure; 14 per cent, because of a combination of all these factors; and only 1 per cent, due to increased industrial use.[3]

It is worth emphasizing that only 1 per cent of water restriction was caused by industry, contrary to common belief. The reason is that industry will not locate where water is in short supply.* Unfortunately, many urban planning boards did not follow this principle in the immediate postwar years and, as a result, housing developments, recreation areas, and shopping centers sprang up without regard to water lines, reservoirs, and treatment plants. A good system of water supply and sewage disposal is the foundation of good community planning and good, healthful living.

* The demands of modern industry (and agriculture) for water, however, have reached fantastic proportions. For instance, in Texas, over a 50-year period, population increased 287 per cent while the use of water jumped 7,000 per cent!

Cost of Program

Defining the problem further, the most challenging factor in the present water crisis has been more and more and still more people. Just as school boards found that when more people came along to be taught, new facilities had to be added, so are we finding ourselves at the crossroads of decision about our water needs. And that decision, of course, involves money.

If we make an effort today to catch up with our population needs, what will an adequate water system cost? To answer that question, it is necessary to interpret a few more population figures. Since 1940 the major increase in population—from 132,000,000 then to more than 175,000,000 today—has been in urban areas. The population dependent on public water supply has risen from 82,000,000 to almost 130,000,000. Meanwhile the advent of such appliances as automatic washers has increased the per capita daily consumption from 122 gal to 150 gal.

By 1975 about 160,000,000 people will live in communities with public water supply and their per capita needs will be approaching 200 gal daily. To meet these needs we must spend around 20 billion dollars on adequate water facilities. Add to this the need for sewage treatment plants, and our total outlay for these inseparable public works facilities should be 44 billion dollars, or an average of 2.6 billion dollars a year until 1975.

Is this an unattainable objective? Of course not, especially when one realizes that an increase in water rates of approximately 1.5 cents a day per capita would eliminate all our accumulated water supply deficiencies.

Money, however, is not the basic problem. The big problem is people.

In 1958, of the thousands of communities with inadequate water and sewage facilities, only 600 or so were concerned enough about the problem to put bond issues before the voters. Many of these towns were under considerable state or federal pressure to clean up pollution. Yet the citizens in nearly one-quarter of the 600 municipalities voted down the issues at the polls.

This is not to imply that nothing is being done about the water facility problem. On the contrary, a number of cities are doing a remarkable job. One outstanding example is St. Paul, Minn. Milton Rosen,[4] commissioner of public utilities, tells the secret of St. Paul's success:

> We in St. Paul, as in many other cities throughout the country, have had a problem in providing an adequate water supply to meet the expanding population and economy of our city during the past 10 years. The last water works bond issue came through in fine order and was carried in every precinct in the city. We appeared before service clubs and labor groups and took our story to the public using every means of communication available. We even distributed literature to the public through our meter readers with this imposing headline: "Water Is the Lifeblood of a City." I might add that the people of St. Paul have never turned down a water works bond issue, the secret being that the full and complete facts are presented to the voters prior to an election.

Public Education

What can we, as spokesmen for the water supply industry, do to alleviate the shortage of water facilities? AWWA is presently engaged in a broad public educational program designed primarily to create a greater awareness and understanding of the problem. We can provide the public and its representatives with documented facts along the lines presented here. We can invite them to look into the adequacy of the water system in their communities and determine for themselves what action is needed. We can suggest some questions for them to ask:

Is the community's source of water supply adequate to meet the increased demands during summer dry periods?

Will the transmission lines be adequate in 1965?

Is the water safe, palatable, soft, clear, nonstaining, noncorrosive, and free of flammable gases?

Will the sewage treatment plant be adequate in 1965?

Will the water utility be ready and able to provide the community with all the water it needs, when and where it needs it, next year and in the years that follow?

Standing ready to aid in any educational program at the local level is the American Water Works Association, through its Water Utility Advancement Program. Each local utility manager can coordinate the work we might do in concert with representatives of state and local organizations.

Summary

1. The most neglected public works problem in America today is our water supply facilities. They are inadequate to meet the needs of our mushrooming population.

2. The problem is so acute in many urban areas that, on a hot summer day, almost half the people are exposed to the danger of insufficient water to put out a major fire.

3. Although safe to drink, the water in the average community would probably not pass the quality standards that

are recommended by water utility engineers.

4. The inadequacy of our water supply facilities constitutes a serious threat to public safety, health, and welfare.

5. We must start *now* to correct the problem. In 25 years our water needs may well be 270 per cent of what they are today.

6. Water is the biggest bargain in the family budget. To provide proper water facilities will be no strain on the pocketbook. We can have a system that will do the job for as little as 1.5 cents more per person a day.

Adequate water supply is indeed a challenge—a job that we all must face up to and get done. But it is more than that, because it requires great purpose and dedication. Perhaps when you weigh the water problem in its broadest implications, you will think of it as a mission.

The key to the problem is public understanding. Without favorable public opinion, no program, ideal, or philosophy can succeed. With it, nothing can fail.

References

1. THOMPSON, E. T. The Worst Public Works Problem. *Fortune* (Dec. 1958).
2. PORGES, RALPH. Summary of 1955 USPHS Survey of Treatment Facilities in Communities of 25,000 and Over. *Jour. AWWA,* 49:1567 (Dec. 1957).
3. FAUST, R. J. Where Are We and Where Are We Going? *Willing Water,* 3:2:3 (Feb. 1959).
4. Private communication.

Puerto Rico Aqueduct and Sewer Authority

Rafael V. Urrutia

A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Rafael V. Urrutia, Exec. Director, Puerto Rico Aqueduct & Sewer Authority, San Juan, Puerto Rico.

PUERTO RICO has a population of 2,314,000 inhabitants in an area of 3,435 sq mi, or a population density of 673 per sq mi (Fig. 1). Obviously, social, economic, and public health problems are manifold. Responsibility for solving two of these problems, the supply of drinking water and the disposal of sewage, rests with the Puerto Rico Aqueduct and Sewer Authority.

Each of the 75 cities and towns is now supplied around-the-clock with drinking water that meets the USPHS requirements for potable water. The total urban population supplied is about 1,000,000. In addition, about 580,000 of the 1,300,000 Puerto Ricans who live in rural areas are also served by the authority. Moreover, 63 cities and towns now have sanitary sewer service and six additional systems are being constructed. For the remaining six towns, appropriations have been obtained from the commonwealth government and surveys are under way. The authority is constantly striving to expand and improve both the water supply and sanitary sewer service.

Economic Growth

The Puerto Rican economy continued to advance during the fiscal year 1957–58, despite the sharpest mainland recession since World War II. The rate of economic growth in Puerto Rico was stable, at about 4 per cent. This growth was the result of a 7 per cent rise in gross product offset by a 3 per cent rise in prices.

The record level of investment during the last 2 years is perhaps the best evidence of confidence in Puerto Rico's economic growth. The share of current production dedicated to investment in new construction, machinery, and equipment once again amounted to 21 per cent.

Real per capita personal income rose to $480 in 1958. Net migration, especially to the continental United States, has decreased to about 26,000 people in 1958, as compared to 62,000 in 1956, owing to the recession on the mainland.

Expenditures for economic development, which include industrial and agricultural developments, transportation, and communication, increased to $49,000,000 in 1958. They amounted to 20 per cent of the total disbursements of the Puerto Rican government in the past year.

Creation of the Authority

Until 1941, it was a generally accepted traditional theory in Puerto Rico that water and sewerage services should be supplied by the municipalities. The government of the capital city, San Juan, however, had willingly made arrangements to supply water to

four adjacent municipalities. All the systems were greatly run down and the service was inadequate both in quantity and in quality. Only six towns had water service 24 hr per day.

At the end of 1941 a bill transferring all the public water supplies from the hands of the municipal governments to an agency of the commonwealth, was passed by the legislature. This law did not come into effect until 1945 because of legal objection from the municipal government of San Juan which, in the absence of adequate compensation, refused the transfer, considering it unconstitutional. The Supreme Court of Puerto Rico decided that, because the municipalities and the public corporations are both "creatures of the state," the only thing that the law implied was a change in the administrator of the properties, and the transfer was declared legal despite the absence of compensation. Nevertheless, the authority honored the outstanding debts of the systems which were payable from revenues.

Simultaneously with the consolidation of the water systems into one organization, the Puerto Rico Sewer Service was created by law as a dependency of the Puerto Rico Department of Public Works, to manage all sanitary sewerage systems. Both services were grouped in 1945 into the Puerto Rico Water and Sewer Service. During its first years the agency received grants-in-aid from the commonwealth government, used not only for new facilities but also to defray administrative expenses because income was not enough to cover expenses. Finally, Law 163 of 1949 brought to life the present Puerto Rico Aqueduct and Sewer Authority. This governmental instrumentality, which functions as a public corporation, was the response to the need for better facilities.

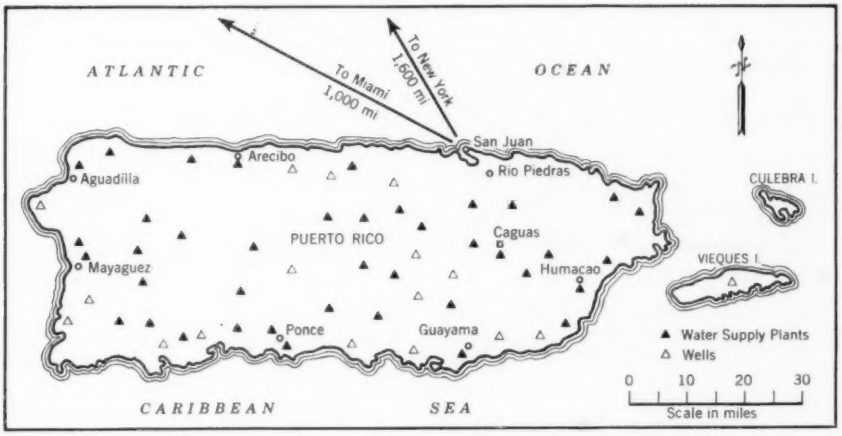


Fig. 1. Map of Puerto Rico and Water Supply Facilities

Shown are the cities and towns of Puerto Rico and the distribution of water supply plants and deep wells.

Authority Organization

A governing board executes the powers of the Puerto Rico Aqueduct and Sewer Authority. This board is composed of five members ex-officio, namely, the governor of Puerto Rico and the secretaries of public works, health, treasury, and labor. The board appoints an executive director, controller, and treasurer. The executive director, according to the law, is the senior officer of the authority.

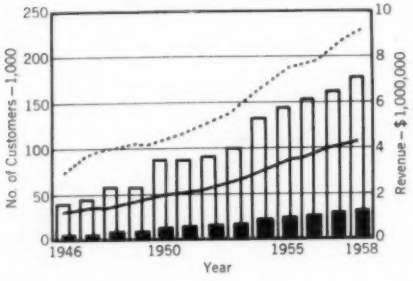


Fig. 2. Customers and Revenue of the Puerto Rico Aqueduct and Sewer Authority, 1946–58

Open and solid bars represent water and sewer revenues, respectively. The dashed and solid curves represent water and sewer customers, respectively.

For administrative purposes, the authority is comprised of the following divisions: legal, engineering, executive, operations, finance, systems and procedures, general services, personnel, and treasury.

Interagency Relations

Even though the authority, as an autonomous agency, maintains services of purchasing, accounting, transportation, warehouses, and treasury independently of those of the commonwealth, there is no danger that it will run wild within the broad framework of the commonwealth government. The composition of the board precludes the possibility of conflict between the policy of the authority and general Commonwealth policy.

All projects for permanent improvement require the previous approval of the department of health and of the planning board of Puerto Rico. Moreover, all transactions are audited for fiscal control by the office of the controller of Puerto Rico, whose reports are submitted to the governing board, to the legislature, and to the public press.

Economic Assistance

Not one of the water supply or sanitary sewer systems which the authority received in 1945 was self-supporting. Despite the fact that the rates approved by the municipal governments and by the public service commission were supposed to defray at least the expenses of operation, maintenance, and depreciation, they were not, in fact, enforced, and the income was therefore always insufficient. The municipalities helped to pay the expenses from other sources of income. To defray the cost of new works, they levied new taxes.

Rates

The law provides that wide publicity must given to all suggested changes and that public hearings be held before final approval by the governing board.

One of the first steps taken by the authority was the introduction of uniform rates throughout the island, effective Jul. 1, 1946. The rates were sufficiently low to place water service within the reach of the great mass of the people but high enough to cover

all the expenses of operation and the amortization of the debt which it was necessary to incur for new facilities. Three important stipulations in the rate structure were: (1) the establishment of a minimum charge which should be paid even though no water is consumed; (2) consideration of the government as any other customer with no privilege of free water service; and (3) a charge for sanitary sewer service, for those connected to the sewers, at cubic meter in excess of 20,000 cu m bimonthly. The customers are billed every 2 months, with the exception of large consumers such as schools, hotels, and factories, which are billed monthly.

Of course, many people cannot enjoy piped water service in their homes either because of low income or because they are located some distance from the water mains. For their benefit there are some 3,300 public fountains installed at convenient loca-

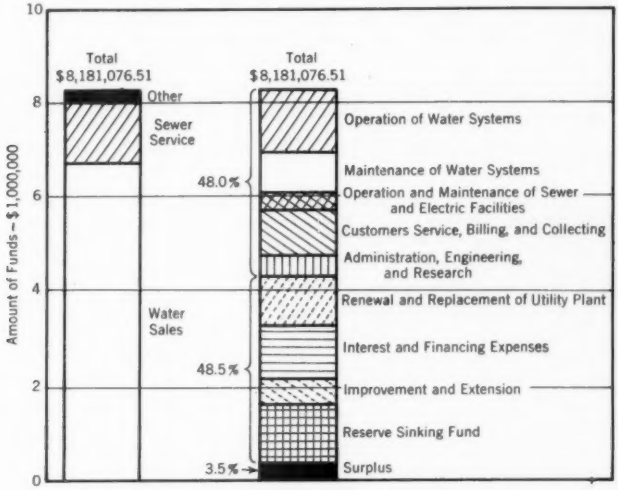


Fig. 3. Sources and Uses of Funds, 1957–58

the rate of one third of the cost of water service.

The continued rise in the cost of materials, services, and labor forced the authority to raise the rates in 1949 and again in 1953.

Uniform rates are binding all over the island upon every class of water user. At the present time, the first 20 cu m (5,284 gal) of water costs $0.105 per cubic meter (264.2 gal). Above that quantity, the price gradually decreases until it reaches $0.035 per

tions all over the island. It should be pointed out that, because the authority is prohibited by law from giving free water, the government pays for this service.

At the close of June 1958, the authority was serving 220,030 customers, 87 per cent metered, who paid $6,809,687; 100,284 sewer customers, who paid $1,176,701; and 1,522 electric-service customers, who paid $71,605. These revenues, added to $123,084 from investment of authority

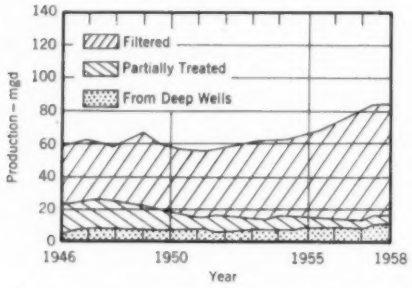


Fig. 4. Classification of Water Supplied by Treatment, 1946–58

Of the present total production of 90 mgd, 89 per cent is fully treated and filtered at 36 plants, which serve 53 towns and cities.

funds, produced a total of $8,181,076 (Fig. 2, 3).

Financing of Urban Works

As the urban water supply systems are self-supporting, it is easy for the authority to borrow money to improve and to expand them. In 1949 the authority floated its first issue of revenue bonds in the amount of $22,700,000 to carry out its first 5-year program. Unfavorable market conditions later prevented the sale of new bonds when needed, but the authority obtained short-term loans from the Government Development Bank for Puerto Rico and from its own trustees.

At the beginning of 1957 the authority sold another $12,000,000 in revenue bonds in order to continue its program of capital improvements. The bonds are payable solely from the net revenues of the authority. Neither the credit of the commonwealth, nor of any of its municipalities or other political subdivisions is pledged for the payment of the bonds.

In 1945 there were only eleven filter plants serving fourteen towns; eighteen other towns depended on deep wells and 43 had partial treatment plants. Of the total production of 50 mgd, 17 per cent went to the consumers without any kind of treatment.

Water production at present is 90 mgd, 89 per cent of which is fully treated and filtered in 36 plants serving 53 towns and cities (Fig. 4). Another group of seventeen towns, which uses 7 per cent of the total production, is served water from deep wells, after a slight chlorination. Thus, 70 towns in all are served with water meeting the USPHS standards; this amounts to 96 per cent of the total production. Moreover, all this water is fluoridated to a concentration of 0.8 ppm fluorine. Partially treated water served in the remaining five towns also meets USPHS standards. In two of these towns filter plants are now under construction, and the remaining three towns are scheduled to have filter plants during the next fiscal year.

The Loiza Project, comprising a dam impounding 6.5 bil gal, a hydroelectric plant, a 48-in. diameter force main, and a filter plant with a nominal capacity of 30 mgd and built at a cost of $12,000,000, is the outstanding public water supply project.

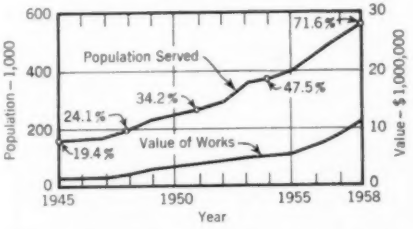


Fig. 5. Value of Rural Aqueduct Works and Populations Served, 1945–58

Of an estimated total program of $30,000,000, $12,000,000 has been invested in rural water supply.

Financing of Sewers

Up to now, because of the relatively low rates for sewer service, the commonwealth government has assumed the obligation of defraying the cost of construction of sanitary sewers in the towns where there are none. The authority has the responsibility of operating and maintaining these systems with its own funds.

By its political association with the United States, Puerto Rico is a beneficiary of the Water Pollution Control Act, which provides federal assistance for projects which prevent contamination of bodies of water. This contribution has already benefited Puerto Rico—this last year by more than $1,000,000—especially for the most important project accomplished by the authority, the San Juan Metropolitan Sewerage System, which cost $32,000,000. Recently the 24-mgd primary treatment plant, which cost $5,800,000, was inaugurated. Trunk sewers varying in sizes from 21 in. to 90 in. are under construction.

Financing of Rural Systems

The rural water supply program has deep social and economic significance in Puerto Rico. Owing to the high population density, all surface bodies of water are contaminated and rural citizens have frequently been victims of waterborne diseases in the past. Upon supplying them with safe water, three purposes are accomplished: (1) prevention of disease which would be ultimately translated into expenses for the government for medical attention and hospitalization; (2) improvement of the public health with a resulting increase in productive capacity; and (3) discouragement of migration from the rural areas to the slums of the cities.

Recognizing those advantages and because such projects could produce little income, the government assumed the responsibility of appropriating the funds for their construction and for any loss arising from the operation of the system. On Jun. 30, 1958, 580,000 country dwellers, who represent 71.6 per cent of the ultimate goal of 800,000, were being served at a cost of $12,000,000 (Fig. 5).

Utility Plant

The transferred utility plant increased from $20,000,000 in 1946 to

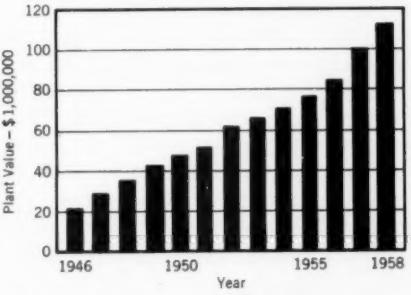


Fig. 6. Value of Utility Plant, 1946–58

In just 12 years, utility plant value has grown from $20,000,000 to $109,000,000, or an increase of more than 500 per cent.

$109,000,000 during 1958 (Fig. 6). The increase came from: value of the properties transferred from the municipalities (14 per cent), contribution of the federal government for the San Juan system during World War II (3 per cent), appropriations by commonwealth government (27 per cent), bond issues and bank loans (32 per cent), authority revenues (13 per cent), and contributions from private developers and consumers (11 per cent). The authority's funds proper constitute the higher share, amounting to 45 per cent.

Conclusion

The history of the Puerto Rico Aqueduct and Sewer Authority should be interesting to those who are concerned with the ways in which a government of scanty economic resources can help solve public health problems. In Puerto Rico the public corporation has turned out to be a very effective instrument to that end. The government itself, upon creating the authority, bestowed upon it the autonomy and flexibility necessary to enable it to improve service vastly in just a few short years.

Discussion

Harry E. Jordan

Consultant to the President, American Water Works Association, New York, N.Y.

The American people can take pride in the achievements of the Puerto Rico Aqueduct and Sewer Authority, as well as in the overall conduct of affairs within the Commonwealth of Puerto Rico. Spectacular progress is being made in the fields of economic and social advancement.

The author has modestly understressed the rapidity with which water and sewage works have become available to the people since 1945. This result is due in part to the grants-in-aid for both water and sewage works construction, but more to the adoption of high management principles by the authority and to the strict honesty with which its business has been conducted.

The adoption of the basic principle that no free water be furnished is a superlative management policy. The fact that the government pays the authority for the water in public fountains used by people without piped water on their premises evidences a consistency in practice which is praiseworthy.

This brings to mind the opposite attitude among the British. They hold the opinion that the water purveyor should never discontinue service to enforce the payment of bills and that the water authority is socially obligated to supply water to all households. Puerto Ricans, on the other hand, believe that the community as a whole, rather than the water utility, is responsible for paying the water bills of needy citizens.

The author has presented a clear and forthright account of the operations of the Aqueduct and Sewer Authority. What he has written merits careful reading and rereading.

Long-Range Planning by Water Utilities

Ernest W. Steel

A contribution to the Journal by Ernest W. Steel, Prof. of Civil Eng., Univ. of Texas, Austin, Tex.

ONE present-day trend is rapid expansion of cities and the development of metropolitan areas around them. Combined with this trend is an increase in per capita water use and in the water demand of industries. These factors, together with the regrettable tendency of city councils or water boards to focus their attention on current problems only, have resulted in serious deficiencies in many water supply facilities that will rapidly become worse. Certainly, the city that neglects to make long-range plans is not only endangering the comfort and safety of its citizens but is also handicapping itself in the competition for more industries.

That present water supply deficiencies are serious is indicated by a report of USPHS on conditions in 1955.[1] Of the water utilities surveyed, only 4.2 per cent reported no deficiencies; 41.2 per cent reported deficiencies in source of supply; 40.5 per cent in treatment facilities; 57.4 per cent in the distribution system; 37.8 per cent in pumping; and 72.2 per cent in storage. These numerous deficiencies seem to indicate either that long-range planning is not common practice or that if such plans are made they are not followed. In all probability, the former condition is more common.

Responsibility of Management

There are reasons why long-range plans are nonexistent in many cities. The utility manager is a busy man who gets little encouragement when he suggests the large expenditures that frequently can be foreseen, even though the need for fund raising and spending may be years away. He has a tendency, therefore, to recommend in his annual report those improvements that are obviously and immediately necessary, improvements that are too often ignored by the city government.

The utility director should be the initiator of a long-range plan. The fact that the deficiencies cited by USPHS were obtained from reports of these officials indicates their awareness of existing conditions. The director should, however, consider future conditions; if he has no time to do so, he should request the assistance of an engineer.

Acceptance of a plan may be facilitated if community leaders are acquainted with utility needs and the advantages of formulating and following a plan. Civic leaders, like average citizens, take water supply for granted. It is important, therefore, that chambers of commerce, service clubs, and influential persons understand utility needs and the scope of a proposed plan. A potent argument to convince community leaders that an adequate supply of high-quality water is necessary, emphasizes industry's attraction to such a supply. Another convincing point is that when many industries move to a community, they become important tax payers, and homeowners' property

taxes are kept down. Because the personnel of policy-making bodies will change during the period covered by the plan, it will also be the responsibility of the water utility director to keep the public and city government aware that a long-range plan exists.

The utility manager who promotes a long-range plan must understand what the plan should include, the technique of making the plan, and what data on existing conditions an engineer will require. The manager who does not compile at least as much of the information necessary for planning as his personnel and facilities will permit is neglecting one of his duties.[2] The essential information will be the same for large or small water utilities. Larger ones will have engineering staffs that will, as far as possible, anticipate the consulting engineer's requirements.

Scope of Plan

How long a period of time should the long-range plan cover? This question cannot be answered definitely. It will depend on the city and the surrounding area, the water supply source, and, particularly, the ease of enlarging or developing existing or new sources. The plan for Wichita, Kan., covered a period of about 35 years into the future.[3] At Baltimore, where new sources had to be obtained, the period was 20 years.[4] The plan for Dallas, submitted to the city council by consulting engineers in 1958, spanned a period of 25 years, which seems to be the maximum period of time over which managers and engineers feel it safe to make predictions. A plan, when once adopted, should be adhered to. No changes should be made except after careful consideration of their effects on the plan as a whole. On the other hand, a plan should not be inflexible. It should be considered as a guide, subject to modification as new conditions develop. At intervals of not less than 5 years, the plan should be re-examined to determine whether predictions regarding population increase, city annexations, and areal development have been accurate. If they are not, adjustments in the plan will be necessary.

Area Specifications

No city is too small or too large to have a plan to guide its growth. When followed, a city plan benefits utility management by indicating the locations of new thoroughfares, and where and approximately when new areas will be developed; by showing which areas will be industrial, commercial, and residential; and by helping to prevent unexpected changes in existing areas and rapid increases in population.[5] The importance of these factors with regard to the design of the distribution system is apparent.

The area to which the plan will pertain will depend on a number of factors. If a metropolitan area is developing around the central city, and an adequate source of water is available only to the central city, a great areal expansion may be planned. If the city plan also includes a study of the expected urbanization in the metropolitan area, the organization of the water supply system will be greatly facilitated. The city's policy concerning annexation of new territories and its willingness and ability to sell water to suburban communities will be considerations. On the other hand, if the small communities surrounding a city can obtain ample water from their own wells, expansion of the city's supply system will be curtailed.

Population Factor

The population to be served is a primary consideration in the long-range utility plan. This is particularly true where there are no special inducements to attract industries requiring large amounts of water. A population estimate for future periods should be checked by close examination of industrial and commercial trends in the tributary areas of a city. If a metropolitan area is developing and the plan pertains to it, the population estimate should account for this area also. Such an estimate may require a special study of the factors that affect a metropolitan population. The study might be done by an agency especially qualified to analyze and interpret business and industrial trends and relate them to expected population growth. The local chamber of commerce may be interested in sponsoring such a study.

Population data are necessary in order to determine water consumption. In the United States, both total and per capita consumption are increasing. It is estimated that by 1975, the total water consumption in this country will be 64 per cent greater than at present.[6] Per capita consumption of the local population, however, is the important factor for long-range planning, and a detailed study will be necessary to estimate the annual and daily average consumption rates throughout the period covered by the plan.

The present trend is toward higher annual average consumptions. Future estimates in a city can be deduced from trends during the past few years. Kansas City, Mo.,[2] maintains a continuous record of water consumption by meter book areas. This, of course, will show only the average monthly consumption per service, but will be of value for indicating consumption trends. In the Dallas study mentioned before, the predicted annual average consumption for 1980 is 175 gpcd, as compared with a present figure of 135 gpcd.

Data on annual average consumption, combined with data on population and expected industrial use, if the latter merits special consideration in a particular city, will provide the information required for an evaluation of water sources, pipelines from source to city, and treatment plants. Annual consumption will vary with drought years, which will probably result in higher than average consumption rates. Past records should provide the relationship between rainfall—especially in the spring, summer, and autumn—and annual consumption.

Source Investigations

Factors to be considered in relation to the source of supply will depend on the type: river, impounding reservoir, or well. If the supplying river has been gaged over a period of years, its reliability as a source of future supply should have been established. If it has not been established, then gagings and hydrologic investigations should be started immediately. If a large increase of water withdrawal is expected, examination of existing water rights should be made and the possible effects of future upstream watershed development determined.

An impounding reservoir already serving the city should have been constructed only after its minimum safe yield had been carefully estimated. The accuracy of the estimate should have been checked all the time the reservoir was in use. Siltation, surveys of which should be made at time intervals depending on the silt-carrying characteristics of the impounded

stream, may seriously affect yield. The effects of reduction of reservoir capacity and yield should be correlated and applied to future estimates. Such a study will indicate the period of time for which the reservoir supply will be adequate for a city, and if it will become necessary to obtain water from an additional source or to increase the height of the dam.

A well supply will also require careful study. It must be determined whether the static levels of the wells are lowering; whether dry years affect the static levels and if they return to normal when rainfall becomes regular; and whether the aquifers can supply more water to take care of an expected increase in demand. If this information is not known, a ground water hydrologist should be consulted. It must also be determined whether the source of supply used by the city is being tapped by other water users, and to what degree the city's wells are affected. Another point to be considered is that wells have a life span largely dependent on the type of water produced, as well as on the construction of the well. A long-range plan, therefore, may indicate that old wells will have to be replaced and that greater development of a present source or the location of a new one may be necessary.

Pipelines from source to city may be inadequate for future needs and may require replacement or, more likely, the construction of additional lines. The long-range plan will indicate when the additional pipelines will be needed. Their capacity will be related to consumption rates and water storage facilities of the city. Water treatment plants must have a capacity related to maximum daily consumption rates and available storage facilities: the greater the capacity for treated-water storage, the closer may treatment plant capacity approach the annual average consumption. This relationship calls for a study of the cost of additional storage facilities as compared with the cost of additional treatment plant capacity, to determine which is more economical.

Distribution System

A study of the distribution system, with its pumping stations, elevated storage or other storage facilities, booster pumps, and piping system, requires data on maximum hourly and daily consumption rates, together with the maximum rates to be expected over a period of 3–5 days. To the maximum hourly rate must be added the expected fire demand in order to arrive at the peak consumption. The maximum 5-day rate will indicate storage capacity needs. Such information is obtained by daily analysis of water pumpage and consumption records. If, for example, there is one pumping station and one or more storage reservoirs riding the line or served by booster pumps, actual consumption will be the measured pumpage for any one day, plus or minus the quantity of water that has entered the distribution system from storage. To make this determination, not only pumpage records are required; needed also are recording water level gages at the elevated tanks and daily analysis of the records to obtain daily and hourly peak rates. Pressure records are also necessary. Kansas City, Mo.,[2] has 43 pressure-recording stations in its distribution systems which supply valuable information that can be related to variations in consumption.

Data obtained by the above procedures will disclose existing deficiencies in the distribution system. These

should be scheduled for prompt remedial measures, which might call for increased pumping capacity and additional feeder mains, booster pumps, or elevated storage facilities. Future deficiencies will also become apparent if present conditions are related to the expected demands determined from population studies.

Investigation of the existing distribution system will be simplified if the city is divided into districts according to topography, location of main pumping stations, or, if there are several water sources, the districts served by each source. If possible, classification of districts should be limited principally to one type of consumer, such as residential, commercial, or industrial. Subareas are also useful, and segregation of types of consumers may be possible when subareas are outlined on a distribution map. The subarea, because its present and future population and, therefore, its future peak consumption rate will be known, makes it convenient to determine takeoff points. Such data are necessary for a Hardy Cross analysis of the distribution system.

Knowledge of actual or potential deficiencies in the distribution system will facilitate planning for improvements, which may include the construction of new arterial or secondary feeders or the replacement of old pipelines with larger ones. Also to be considered is an investigation of the carrying capacity of existing feeders and the possibility of restoring their capacity by cleaning. A rehabilitation program may also include the relining of pipe in place, which is more economical than replacements.

If the long-range plan envisions extensions into neighboring areas not yet completely developed, new feeder installations can be planned, not only with regard to their size, but also with regard to their connection points with the improved existing distribution system. These feeders will follow existing or proposed arterial highways; locations of future pumping stations and storage reservoirs can thus be established. These sites should be purchased before real estate development causes land values to become greatly increased.

Financial Considerations

Money will be needed to carry out a plan, and cost estimates may seem so high as to be discouraging. It should be recognized that what is costly is not the plan itself but the improvements that will be necessary if the water utility does its part in providing for the future needs of the city. The plan allows for a time schedule of improvements and a similarly timed financial plan to take care of the costs. Inasmuch as it may become necessary to borrow money, a financial plan should be designed for integration with the total debt program of the city in order to prevent a fiscal bottleneck that would delay a vitally necessary improvement program. Such a financial plan would also be useful when decisions have to be made about which improvements are to be paid for out of current revenues and which ones are to be financed with borrowed money.

Costs of improvements are ultimately defrayed by customers. Accordingly, an extensive study of water rates should be made. The existing rates in many cities are too low and have resulted in hand-to-mouth fiscal policies that have prevented orderly development and discouraged forward thinking by water utility managers. A check of existing rates should probably

accompany the formulation of a long-range plan to determine whether income will be sufficient to pay for added operation costs and the debt service.

Conclusion

There are no valid arguments against planning for the future. The magnitude of a 25-year plan may be discouraging, but compromise is possible. A plan for a shorter period of time is better than no plan at all, and there is nothing to prevent the water utility manager of any city, however small, from formulating a plan. Too many water utility managers, unfortunately, are bogged down with the details of their jobs.[7] Some are chiefly concerned with billing, collections, and office procedures. Others believe that their main job is to supervise the distribution system, water treatment, or pumpage. These attitudes are usually not the fault of the manager. Governing bodies, in their zeal to keep water rates low, are in the habit of frowning on suggestions or requests for adequate staffs; possibly, managers have been unduly acquiescent. The competent water utility administrator, however, is alert to the community's future needs and either plans for, or insists on planning for, that future.

References

1. PORGES, RALPH. Summary of 1955 USPHS Survey of Treatment Facilities in Communities of 25,000 and Over. *Jour. AWWA,* 49:1567 (Dec. 1957).
2. HATCHER, M. P. Planning for Future Development. *Jour. AWWA,* 41:705 (Aug. 1949).
3. HESS, R. H. Long-Range Water Supply Planning for Wichita. *Jour. AWWA,* 44:1043 (Nov. 1952).
4. BLACKBURN, S. C. Enlargement of the Baltimore Water Supply System. *Jour. AWWA,* 39:119 (Feb. 1947).
5. AHRENS, G. C. City Planning and Water Works. *Jour. AWWA,* 47:319 (Apr. 1955).
6. Water Use in the United States, 1900–1975. *Willing Water,* No. 38, Supplement (Feb. 1956).
7. FAUST, R. J. The Needs of Water Utilities. *Jour. AWWA,* 51:701 (Jun. 1959).

Changes in Judicial Concepts of Utility Liability

Gerald Remus

A paper presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif., by Gerald Remus, Gen. Mgr., Dept. of Water Supply, Detroit, Mich.

SEVERAL changes have taken place in judicial interpretations of utility liability for damages or bodily injury resulting from broken mains or services in recent years. Three areas have been particularly affected: (1) judicial thinking regarding liability cases in the earlier days; (2) the present trend; and (3) what water utilities may do to keep the cost of damage claims to a minimum.

Judicial Precedents

Courts throughout the United States make very little distinction between privately owned and publicly owned utilities as far as their liability for acts or failures to act on the part of officers or employees is concerned. They hold that, when a municipality undertakes to supply water for commercial, domestic, and industrial purposes, it acts in its proprietary capacity rather than in its governmental capacity and that in its proprietary capacity it is liable for the acts or failures of its employees just as is a privately owned utility.

Liability for damages caused by a broken main or service has usually been determined under the law of negligence. Before proceeding further, it might be useful to examine the meaning of the word "negligence." "Negligence" is a failure to take that degree of care and precaution for the protection of the interests of another person which circumstances justly demand. It is also any conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm.

The courts appear to be in agreement that a public water supply agency is not an insurer against loss caused by escape of water from its mains and services. Because the utility is not an insurer against such loss, it has always been held liable only if negligent conduct, involving either action or inaction, caused the damage. In most states the person suffering the loss caused by flooding from mains or services may not recover damages against the water utility unless negligent conduct can be legally established.

It must be recognized that the conveyance of water through streets and public places in pipe under pressure, with the pipes subject to external pressures and other hazards, does involve an element of risk to persons or property. The necessity for water at all times outweighs these risks by a wide margin, however. It therefore follows that the transportation of water does not involve an unreasonable risk and that the transporting cannot itself be termed negligent conduct. On the other hand, if the damage can be

shown to be caused by faulty installation of mains or services, failure in maintenance, or improper operation, then such conduct or failure to act does involve an unreasonable risk to others and is negligent conduct that may properly involve liability for damages. In other words, if the agents of the water utility can be shown to be negligent in that they failed to act as well trained men should act under the circumstances, then the utility has been guilty of negligence and may be liable for damages.

Types of Liability Cases

There are three basic types of liability cases. The first, which has been upheld by the majority of the courts, is that a public water supply agency is liable for damages or injuries or loss caused by main breaks or service breaks only if it is proved that negligence was the proximate cause of the loss. The burden of proof in this type of case is on the plaintiff.

In the second type, the case is decided under the doctrine of *res ipsa loquitur,* a legal phrase meaning "the thing speaks for itself." Here, again, negligence is an essential element, but the courts have held that if the pipeline was in the exclusive possession and control of the water utility and the utility has exclusive knowledge of the care exercised in the line's installation and operation, and if it also appears that the accident would not ordinarily have occurred without negligence, negligence may be inferred and the burden of proof shifted to the defendant.

The third type of case follows the precedent of an old English case of the 1860's, *Rylands* v. *Fletcher,* which involved the flooding of a mine. Water escaped from a reservoir into an abandoned mine directly under the reservoir and drained from the abandoned mine into the adjacent working mine where the damage was done. The English court held that there was no negligence involved, but that one who maintains on his own property a thing that could cause injury to others if it escaped is liable for damages if the escape occurs, even though no negligence can be proved.

The present Michigan law with reference to utility liability for damages caused by water main breaks states that a municipality is not liable for damages if the break is the first of its kind and if there were no previous reports of trouble with the particular main in question, unless, of course, it could be shown that there was negligence in the construction or maintenance of the pipe.

A. J. Brown and Sons Inc. v. *City of Grand Rapids*[1] is a good illustration of the first type of case. This case involved a flooding of a business place by a broken main; it was relied upon for a number of years in Michigan as the basis for denying liability for damages occurring from water main breaks. It was held in this case that a municipality was not an insurer of its water system and was simply required to exercise reasonable care in the establishment and maintenance of its system. The opinion stated further that actual notice of the defective condition of its water system, either by reason of knowledge of the break at the point of damage or recurrences in the immediate vicinity, would be a prerequisite to a finding of neglect. Liability was denied in this case, as there was no testimony of previous breaks in the immediate vicinity of the point of damage. The decision further stated that the doctrine of *res ipsa loquitur* did not prevail in Michigan. There

have been numerous other cases throughout the country in which the courts have denied liability when negligence on the part of the water systems had not been proved.

Present Trends

A marked change in the concept of liability has taken place across the nation. A recent case, *Weisenberg* v. *Village of Beulah*,[2] illustrates the courts' change of thinking in the field of negligent liability and does apply the doctrine of *res ipsa loquitur*. The village of Beulah, Mich., sold water to paying customers in an adjacent resort community. During autumn of 1952 the plaintiff made arrangements to close his summer cottage and, on Oct. 6, 1952, proceeded to his home. He obtained permission from the village to turn off the service at the service box near the street so that he could open the faucets in the cottage and drain the pipes. He hired his usual plumber to shut off the service, drain the pipes, and close the cottage, and the village clerk was so notified. The actual work of shutting off, draining, and closing occurred on Oct. 7. Sometime between that date and Nov. 6–7, the service was somehow turned on and water ran through the open faucets in the plaintiff's cottage, causing extensive flooding and damage. It was later disclosed that more than 500,000 gal of water flowed into and through the cottage before the unhappy situation was discovered. The plaintiff filed formal claim with the village, which was denied. He then brought suit in court seeking recovery for the repairs, damages, and incidental expenses of restoring the flooded cottage. At the trial the defendant claimed that the plaintiff was never granted official permission to turn off the service himself, and more important, it also denied the plaintiff's allegations that the defendant's employees had negligently turned on the water or were in any manner responsible for the damage.

The plaintiff, in turn, introduced evidence supporting most of his allegations, but was unable to produce any witnesses or testimony directly and clearly establishing that the defendant or its employees had actually turned on the valve. The case was appealed to the supreme court of the state, which upheld the action of the lower court and awarded the verdict in favor of the plaintiff. In reaching its decision, the supreme court stated that a village that sold water to paying customers exercised a proprietary function and had a corresponding duty to inspect the situation, especially after the summer cottagers had left for the season. Thus, although there was no proof of negligence on the part of the village of Beulah, negligence could be inferred, and the doctrine of *res ipsa loquitur* therefore applied. This decision represents a marked change in the attitude of the Michigan court with respect to the imposition of liability.

There was another interesting *res ipsa loquitur* case, which did not involve a water department. In *Mitchell* v. *City of Detroit*,[3] an action for personal injury sustained by the plaintiff while passenger in a bus operated by the defendant city was decided in favor of the plaintiff. There was no proof of negligence on the part of the defendant, and the case was referred to the Michigan Supreme Court. The decision discussed at length the doctrine of *res ipsa loquitur*, and referred to two other leading Michigan cases. *Higdon* v. *Carlbach*[4] and *Indiana Lumberman's Mutual Insurance Co.* v. *Matthew Stores*.[5] The opinion ren-

dered by Justice Voelker, criticized Michigan decisions for, in effect, applying the doctrine of *res ipsa loquitur* even though recognition of its existence as a rule of law was denied. Justice Voelkner said:

> We may add that we seem frequently to apply our own version of *res ipsa* much as a disdainful lady might proclaim her profound adversion to strong drink just as she is tossing off a bumper of patent medicine harboring enough alcohol to floor a stevedore.

Cases in other jurisdictions than Michigan have also held municipalities liable. In *Adam Hat Stores* v. *Kansas City*,[6] the court held that the doctrine of *res ipsa loquitur* was applicable in an action for damages from a water main break brought against a water system owned and controlled exclusively by the city.

The doctrine was also applied in Washington, in the case of *Kind* v. *City of Seattle*.[7] It was held that, in an action to recover for damage caused by a broken water main, the inference of negligence could not be overcome by the city's evidence of due care.

The case of *Sargent* v. *Town of Alton, N.H.*,[8] was decided in June 1958. This was also an action for negligence to recover damages to the plaintiff's building and contents caused by water. The damage was alleged to have resulted from the negligent opening of a valve by a city employee. The case actually hinged on whether or not an admission made by the water commissioner would be admissible in evidence —that is, his alleged statement that the employee must have turned the valve on instead of turning it off. The court held that the statement was admissible and ordered a new trial. This case should, of course, be compared to the Beulah case cited above.

A further indication that the question of legal responsibility of a municipality may well depend on the particular circumstances is found in the case of the *City of Boston* v. *Boston Edison Company*,[9] in which it was held that the question of whether the city's conduct was reckless in failing to take action immediately after notification of an unusual flow of water in an area near a main break was a jury question under state law.

Although the cases cited above show a general trend, it is not intended to convey the impression that the doctrine of *res ipsa loquitur* is completely supported by other states. In Ohio, for example, *National Mattress Co.* v. *City of Youngstown*,[10] the court held that the evidence of alleged negligence was insufficient for a jury. The plaintiff charged that the city had failed to keep a water line in proper repair after the city knew, or should have known through exercise of ordinary care, of its weakened condition; the plaintiff alleged city negligence in failing to inspect the water line, which had been in the ground for 40 years, and in failing to investigate, inspect, and repair the water line when notified that a break existed.

There was also a divergence from the general doctrine in North Dakota in the case of *Taylor* v. *City of Devil's Lake*.[11] Action was taken by owners of a hardware store against the municipality. A water main had broken and the municipality had allegedly been negligent when it failed to shut valves to stop the flow of water into the owner's basement. Water damaged large quantities of merchandise. The court held that because the municipality had purchased and enlarged the water system in order to secure adequate fire protection, the city exer-

cised an essential government function and was not liable for damage to the merchandise.

Defects in Streets and Walks

Liability cases may arise as a result of injury sustained by people who fall or stumble over service boxes that are above grade. In Michigan, prior to a general highway law, no liability existed because of any alleged defects in the streets and sidewalks. However, this statute and its subsections impose a statutory duty upon municipalities to maintain their streets and sidewalks in a condition reasonably safe and fit for public travel. In Michigan it is a general rule that a defect which is less than 2 in. above the surface is not an actionable defect, unless there is an entrapment, and in that instance the height or depression of the defect becomes immaterial. The "two-inch" rule is simply one that has been adopted by the courts of Michigan over a period of years, and, although it is the present law, the present supreme court might well reverse it and has, in fact, indicated in previous decisions that it will. Another important question in Michigan concerning any item that the water department might have on the streets and sidewalks within the municipality is whether or not the utility was aware that alleged defect existed. A Michigan statute states that unless actual knowledge of the defect exists, a municipality is not liable for a period of less than 30 days. If, however, the defect exists longer than 30 days, it is presumed that the city knows of this condition and should have made proper repairs. Water departments should be concerned about this type of liability inasmuch as it applies to repair jobs on mains and services and the resulting settling of a sidewalk or street. Such setting causes, or could cause, a culpable defect.

Michigan has recently changed its procedural rules concerning the proof of negligence. Before the recent change it was necessary, in addition to other facts, for the plaintiff or the party seeking damages to prove himself free from contributory negligence. That provision has been abrogated, however, and it is now incumbent upon the defendant to prove that the suing party was guilty of contributory negligence.

Money-Saving Precautions

Concepts of legal liability are changing, not only in Michigan, but apparently throughout the nation. It is likely that even more liberalism regarding liability will be evident in future court decisions. This trend in judicial thinking is important to everyone in the water industry. Serious thought must be given to what can be done about it. Utilities cannot, of course, change this trend, but they can prepare for it. Perhaps they should start thinking of building up an insurance fund to cover the cost of damages. Such a fund would, in effect, be spreading the cost over the entire system instead of permitting the person suffering the damage to stand the loss, unless a court fight appeared imminent.

There are other precautions that can be taken. Inspection can be improved, not only for meters and meter installations, but also for main and service installations.

Utilities should be more suspicious of unexplained running water and sinking street or ground surfaces along pipeline routes. They should be prepared to follow up with adequate investigations when such symptoms de-

velop. When a break does occur, they must be sure that there is the least possible delay in shutting off a broken main or service. Proper materials should be used to meet anticipated pressure and traffic loads. In the construction of new mains, water utilities should confer with gas, power, and telephone companies to determine the locations of their installations in relation to proposed new routes. Other utility installations alongside, over, or under water mains can make repair work difficult. In the backfilling of trenches, care must be exercised that the backfill is properly made.

Water utilities should make ready use of testing laboratories to test the materials they use. Adequate records of testing activities and materials can often help to back up statements in courts of law, as can good standards of construction and materials.

Detroit has long had a policy of using pumps and personnel at no cost to the customer to pump out and clean out a basement that has been flooded by a main break. The utility also has a policy of rehabilitating lawns and putting in new sidewalks and driveways that have been damaged. These policies have probably saved a large number of claims.

Conclusion

The author is convinced that there will be more and more judgments of utility liability in the future, and that this will be aided by future decisions of the supreme courts of the various states. That has been the trend of decisions of Michigan Supreme Court during the past year. These decisions have imposed greater liability upon municipalities and have partially negated the defenses that a city formerly had in these actions for negligence. Some way to absorb some of these losses must be sought, for it may well be that the doctrine of *res ipsa loquitur* will impose more and more liability upon water utilities.

References

1. *A. J. Brown & Sons Inc.* v. *City of Grand Rapids.* 265 Mich. 465 (1933).
2. *Weisenberg* v. *Village of Beulah.* 352 Mich. 172 (1953).
3. *Mitchell* v. *City of Detroit.* 355 Mich. 182 (1959).
4. *Higdon* v. *Carlbach.* 348 Mich. 441 (1957).
5. *Indiana Lumberman's Mutual Insurance Co.* v. *Matthew Stores.* 349 Mich. 441 (1957).
6. *Adam Hat Stores* v. *Kansas City* (Kan.) 307 SW 2d 36 (Oct. 1957).
7. *Kind* v. *City of Seattle,* 312 P. 2d 811 (Jun. 1957).
8. *Sargent* v. *Town of Alton* (N.H.). 143 A. 2d 411 (Jun. 1958).
9. *City of Boston* v. *Boston Edison Co.* 260 Federal 2d 872 (Nov. 14, 1958).
10. *National Mattress Co.* v. *City of Youngstown* (Ohio). 153 NE 2d 439 (Mar. 1957).
11. *Taylor* v. *City of Devil's Lake* (N.D.). 87 NW 2d 401 (1958).

The True Price of Accidents

George C. Sopp

A paper presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif., by George C. Sopp, Joint System Head & Asst. Mgr., Dept. of Water & Power, Los Angeles, Calif.

IN an age of tremendous industrial expansion, when construction and operation costs are continually rising, it is more important than ever that water utilities take every precaution to minimize unnecessary expenses. The growth in national population and industrial production has had, and will continue to have, a gigantic impact on the water industry, and it can be expected that water utilities will be called upon to spend more and more money to expand present facilities and provide more water. One area in which it is still possible to effect major economies is safety. The amount of money needlessly wasted on accidents in the water industry each year is astounding.

Accident Problem

Accidents are a natural, if unnecessary, outgrowth of technologic progress. In the nineteenth century, Southern California had many *zanjeros*, or ditch tenders, who were one-man water departments. Their function was to divert water from a main *zanja*, or ditch, into the ditches belonging to their customers. The *zanjero* had no accident problem to speak of; his only tool was a shovel, and he was an expert in its use. In time, wells were dug or drilled, wooden mains were laid, and treatment plants were built. Today great aqueducts carry water more than 300 mi to serve Southern California; the use of heavy equipment, dangerous treatment chemicals, and high-powered machines presents new hazards to the water utility employee.

Accidents are not only more frequent today; they are also more expensive. Damage to valuable equipment, suits for damages resulting from accidents involving the public, and the loss in production created when a single employee is disabled—not to mention the expense of workmen's compensation and other benefits common in today's complex society—all these are costs the *zanjero* could not even have imagined.

Costs of Accidents

According to the National Safety Council, the cost of accidents reached an astronomical sum of more than twelve billion dollars in 1958. This includes both on- and off-the-job accidents (Fig. 1). Employers, whether they know it or not, pay a large part of the cost of off-the-job injuries, either directly in "sick pay," or indirectly in reduced employee efficiency. An off-the-job injury is a definite factor in the cost of operation.

The more than twelve billion dollars expended yearly on accidents becomes even more significant when viewed from the point of view of what it could have provided in the way of community needs. The public school system in the United States, from kindergarten through high school, costs six

Fig. 1. An Accident in the Making

During 1958 alone, 77,900 people died in off-the-job accidents. Business and industry paid a large part of the cost in lost manpower.

billion dollars annually, including the cost of new buildings, equipment maintenance, and teachers' salaries. The money now wasted on accidents could pay for this and still leave more than six billion dollars, a sum large enough to operate all the nation's hospitals for a year.

But the money cost of accidents is minor compared to the toll in human suffering. Every 30 min, five people in the United States lose their lives through accidents, and 548 more are injured—and this goes on hour after hour, day after day. In view of these facts, there can be no moral justification for not vigorously prosecuting a program to reduce the terrible burden of accidents.

The dollar costs of accidents penetrate into every phase of an organization's operation. Indeed, the true cost is almost impossible to determine. One minor accident, for example, in which two aircraft contacted one another on the ground while taxiing, seemed to cost a modest $193 in repairs. Management knew there were other, hidden costs due to loss of revenue, idle equipment, deadheading of replacement aircraft, and shifting of passengers and crews. The real cost was found to be nearly $19,000, although $193 was all that showed on the surface.

The accident situation is rather like the car that "nickels and dimes" its owner to death. Finally, when the car breaks down altogether and the owner is faced with a huge repair bill, he decides that this, on top of the other expenses, is the last straw. It is only then that he decides to do something to correct the situation.

The nearly twelve billion dollars needlessly wasted on accidents each year is only part of the cost; the greatest cost cannot be measured. No one can measure the damage to a home and family when a member of that family is seriously or fatally injured. The deep scars left by serious accidents and the many unmeasurable costs directly and indirectly connected with them affect every phase of community

Fig. 2. A Typical No-Injury Accident

Although no one is hurt, accidents like this cost money in lost time and damaged equipment.

life. How many luxury items can a widow and her children buy from compensation payments?

Everyone has a legal responsibility to aid in the prevention of accidents. There is also a moral responsibility that cannot be ignored. There can be no moral, legal, or financial justification for risking the success of a company by failing to carry out an effective accident prevention program.

Accident Frequency Rates

Accidents cut into an organization's efficiency to an extent often unrealized (Fig. 2). It is an unfortunate fact that managements of many companies are not actually aware of the safety performance of their own organizations as compared with others in the same field. The hypothetical "Ajax Water Co.," for example, has 100 employees. They experienced eight lost-time injuries last year. That does not appear to be an excessive number and management may feel that no accident problem exists. The safety performance of organizations can be closely calculated and compared by using an accident frequency formula, however, and when this is done, a water utility with an apparently modest number of accidents may actually reflect a greater frequency of accidents than the mining industry, with its high degree of hazard from cave-ins and explosives, or the lumber industry, which ranks with mining as one of the most hazardous fields.

Accident frequency rates are calculated by multiplying the number of lost-time injuries by 1,000,000 and dividing by the number of man-hours worked. This method is used because it can be applied to ten employees or 10,000, and gives the number of injuries per 1,000,000 man-hr of exposure.

If "Ajax Water Co." lost-time injuries are computed in this way, their accident frequency rate is found to be 39.84, a frequency far above that of the two hazardous occupations mentioned above. "Ajax Water Co." *has* an accident problem, but it is hidden and will go unrecognized until someday a major accident will awaken the management to the seriousness of the problem; unfortunately, it may have cost someone's life by then.

Fig. 3. Easier, But More Dangerous

Misuse of modern tools and appliances causes many serious injuries each year.

Causes of Accidents

The accident problem has increased because of many factors. Technologic advances, although they have increased production and made work easier, have often created new accident problems. A service crew working on a city street every day faces serious hazards from motor vehicles and must be alert to pedestrian safety. Modern installations and facilities call for increasingly

heavy types of construction equipment and materials. Because of misuse, improper operation, and just plain thoughtlessness, many labor-saving tools and appliances needlessly take a heavy toll of human life. In the days of the handsaw, the loss of a finger or hand was an infrequent occurrence. Today, with the power-driven saw, many "do-it-yourself" enthusiasts and even professional craftsmen have lost fingers, limbs, and even their lives from this one tool, which, although it can do the work of ten men using handsaws, can and must be used safely (Fig. 3).

Fig. 5. Supervisors' Safety Meeting

It is easier to solve accident problems in advance. The supervisor, because he has direct control over his men, is in the best position to cut accident costs.

Safety Programs

The question of what can be done to prevent accidents often arises at management meetings. Unfortunately, there is no one clear answer. Accident problems differ from the normal operational problems of a water utility, in that accidents are primarily caused by human failure.

If a distribution system needs improvement, an engineer can design the necessary changes and installations on paper and the objectives of the project are virtually insured. The top executive may need to give the project little or no attention because it is resolved satisfactorily at a lower level of supervision. Not so with a safety program, for to effect any noticeable improvement, top management *must* devote considerable time not only in planning, but also by taking a position of active and vigorous leadership. Any improvement in safety performance will be in direct proportion to the effort exerted by management (Fig. 4). If a safety program is to succeed, managers and supervisors must not only provide enough thrust to launch the project, but they must also sustain the program with enthusiasm and active support (Fig. 5).

Fig. 4. A Life Saved

The heavy bolt shown fell 40 ft, striking a workman's hat. No injury occurred, but without the hat the man would almost certainly have been killed.

The first step toward safety is a series of meetings embracing all levels of management to plan and map out a program that will be comprehensive and vigorous enough to achieve results. Any effort less than the best is not enough, because half-hearted attempts invariably climax in program failure and disappointment. The development

of safety consciousness is an elusive thing, not unlike the development of morale. It cannot be accomplished by a directive or order, no matter how firm or well stated. This is another way in which accident prevention differs from usual water system problems. Everyone wants to develop good morale among employees, and everyone knows that it cannot be developed overnight. It is something that must be carefully nurtured over the years, something that must be gradually built into the philosophy and employee relations structure of the company.

Safety consciousness is the same in this respect, because it, too, can be achieved only after careful, sometimes painful, effort. As a matter of fact, safety and morale go hand in hand; an organization's safety performance is a primary index of employee morale, and often a good index of production and efficiency as well.

Types of Accidents

A look at the three major groups of accidents may point out more clearly how the national accident cost is developed.

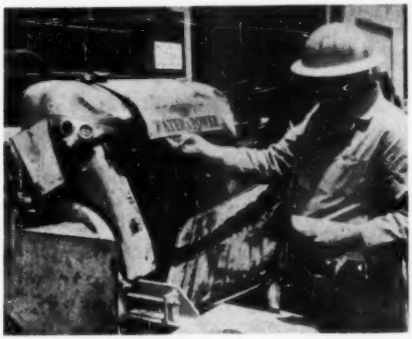


Fig. 6. More Than Meets the Eye

At first glance, there is only a piece of damaged equipment, but delay of the job and the enforcement of idleness on a crew help to boost costs even further.

Fig. 7. Result of Improper Loading

Damage to these meters could have been avoided by proper training.

Equipment Damage

The first type is the accident that damages equipment, structures, or materials; it usually is not grouped with industrial accidents because personal injury is not involved (Fig. 6). In most instances, however, investigation shows that only a fortunate combination of circumstances prevented a personal injury. Repeated occurrences will sooner or later result in personal injury.

The cost of this type of accident may be considerable (Fig. 7).

In the Los Angeles Department of Water and Power, for example, a truck driver was recently transporting a pipelaying crane to another job location. Just prior to his departure from the first location, the crane operator used the crane, while it was on the truck, to unload a fire hydrant. He then failed to lower the boom to a safe position for transporting. The driver, not observing this unsafe condition, drove off with the boom raised almost

to its full height (Fig. 8). Soon afterwards, the truck was driven under a railroad overpass and, because of insufficient vertical clearance, the boom struck the concrete structure and was bent into a shapeless mass. Total repairs cost $980.00. Only good fortune prevented the crane from being pulled off the truck and falling onto the highway. It is impossible to evaluate the extent of the damage that might have resulted if the crane had fallen into the path of an automobile or loaded school bus.

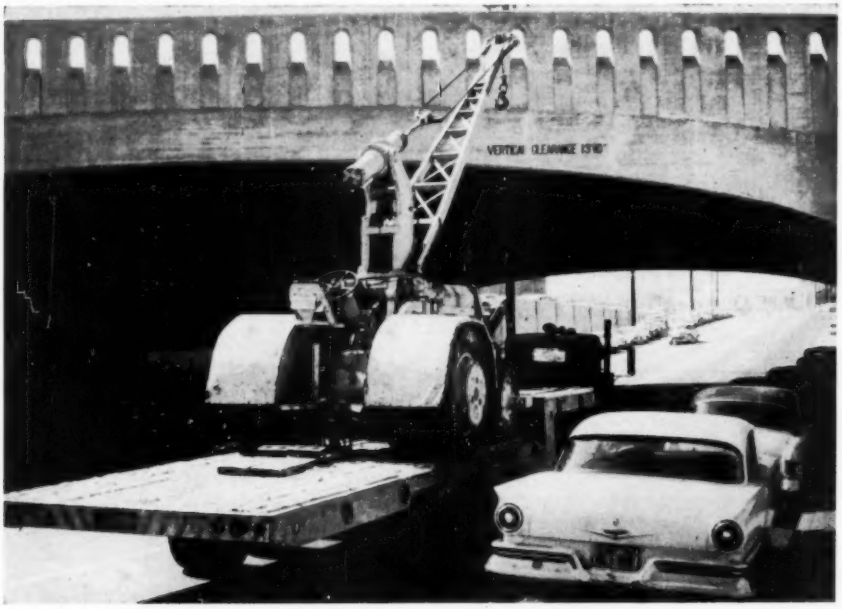


Fig. 8. Impending Tragedy

Fortunately, no one was injured when the crane finally collided with the overpass, but such an accident could have resulted in several deaths. As it was, the cost ran to nearly $1,000.

Employee Injuries

The second type of accident is that in which injury to an employee is the only factor. For example, a warehouseman who suffers a back injury from improper lifting may be incapacitated for a day and cost the company $35 in medical expenses and lost time. If a laborer trips, falls into an excavation, breaks his leg, and is off duty for several weeks the direct costs of medical treatment and lost time amount to $750.

A pipe installer may receive crushing injuries to his fingers and hand while hoisting pipe (Fig. 9). If he is off duty for 5 days and must be assigned to light duty for 3 weeks after he returns, the cost of the accident is about $190. The dollar cost for lost time and medical treatment alone is

not excessive, but the hidden and indirect costs boost the total even higher.

Several years ago a water department crane was brought into the yard to have a section of boom inserted to gain extra length. The operator lowered the boom and rested the end on a nearby trailer. A maintenance and construction helper took a position under the boom joint and prepared to knock out the fastening pins (Fig. 10). The helper failed to realize the dangerous position he had taken. When he hit the lower pins, they came out easily, collapsing the boom and crushing the helper to the pavement. He suffered a broken back and a severed spinal cord. What a task for an employer to inform the family of a tragedy of this magnitude—a breadwinner hopelessly paralyzed, confined to a wheelchair for life. It is impossible to estimate the total cost of an accident of this type. Because of a moment of thoughtlessness, the home and family of a 40-year-old man were almost shattered; their standard of living reduced to an existence level; and the children's educational plans were curtailed. What of the wife, who has suddenly been sentenced to a life of caring for a hopelessly crippled husband? This is a loss that no amount of money can compensate. Nevertheless, more than $100,000 has been paid by the employer alone to date.

Damage to Public Property

The third type of accident is one in which the only injury or damage is to persons or property outside the company. If an automobile receives a broken headlamp in an accident, and the driver is unhurt, $1.80 will make the car as good as new. But there, in front of the car, lies a child, struck down and killed by the vehicle at a crosswalk. What price can be set on that child's broken body? What is the cost to the parents in shattered hopes and aspirations? What, also, is the cost in damages and the loss of public confidence in the company?

Management and supervision must bear the burden of responsibility for the actions of their employees. If, by indifference or lack of interest, management fails to equip employees to carry out their duties efficiently and safely, it is shirking its duty to the company, its employees, and to the community as a whole.

Fig. 9. Careless Handling of Materials

A signal to the crane operator, given perhaps a second too early, can result in a lost hand'—or worse. Accidents like this one are common, but they can be prevented.

The examples cited above are not isolated or uncommon occurrences. It is almost impossible to pick up a newspaper for 2 days in a row without reading of a similar accident.

The accidents described apparently all resulted from human failure. In

fact, about 85 per cent of all accidents are caused by human errors. A few of the remaining 15 per cent are caused by unsafe conditions and unsafe equipment, which are a contributing factor in a large portion of the other 85 per cent and are the direct responsibility of management and supervision. For example, last year in Los Angeles a flagman was killed by a dump truck that was backing up. A warning device on the truck might well have pre-

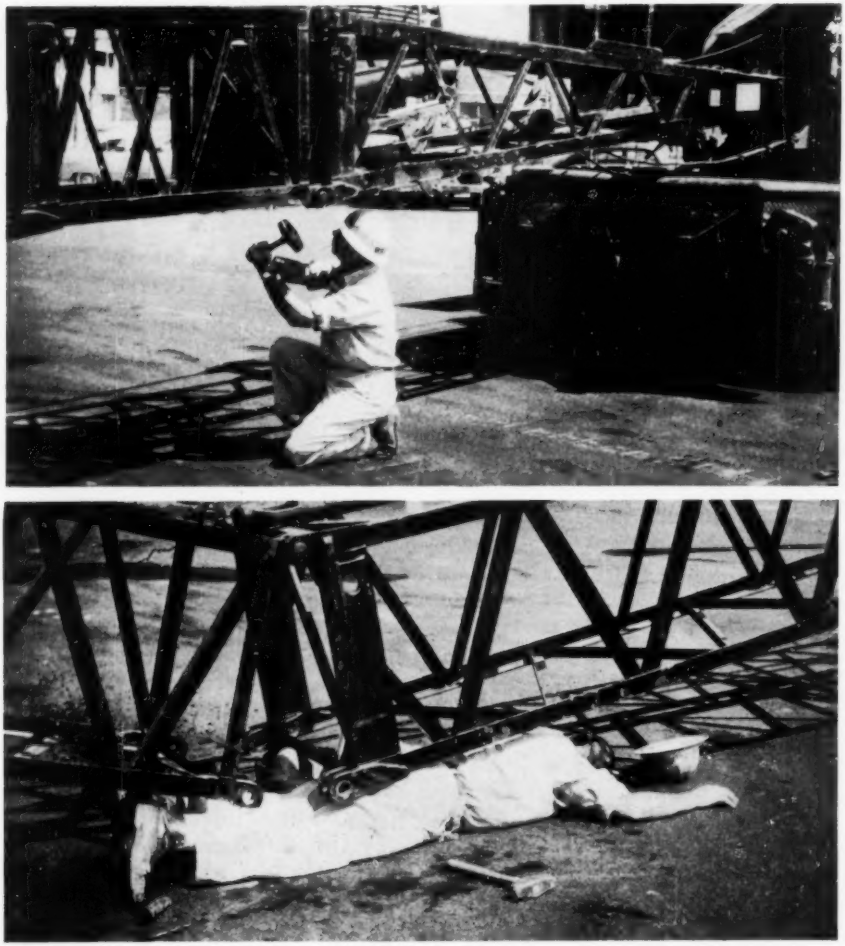


Fig. 10. The Price of Negligence

A moment's consideration could have prevented this tragedy, which resulted in a severed spine and a broken back. The accident has already cost the water utility more than $100,000, and the worker is confined to a wheelchair.

vented this death. Such a device would have cost $36—a small price to pay for a human life.

Fire Prevention

Fire prevention and protection often receive little attention in otherwise well integrated safety programs, but a fire is just as much an industrial accident as an injury to a worker's finger.

A few years ago, the management of a large manufacturing plant in the Midwest received warnings from the local fire department and from the fire prevention engineers of its insurance carrier. Both agencies pointed out that there was great danger of fire because of improper handling of solvents and volatile chemicals. The warnings went unheeded. Shortly afterwards, a welder's torch started a small fire which quickly involved the entire plant. Fire and explosions reduced the buildings to rubble, claimed seven lives, and shut down the plant completely. Property loss alone amounted to more than $500,000.

Management must decide what kind of a safety program is desired, share with supervision in the making of plans for implementation, and insist that the safety program be a regular functional part of the organization and job planning. A successful safety program requires continuous training and education of all levels of supervision in order to reduce accident frequency and severity. Furthermore, if any company is to reach the ultimate goal of zero frequency, it must enlist the active participation of every employee. The safety chain is no stronger than its weakest link.

Fig. 11. Tailgate Safety Lecture

Meetings like the one shown above are the mainstay of a good safety program.

Los Angeles Program

The Los Angeles Department of Water and Power has a very effective seven-point safety program, which,

having functioned for 3 years, has brought about a definite and measurable increase in safety performance. The program is, briefly:

1. Weekly on-the-job safety meetings are held. Material prepared by the department or obtained from various safety agencies is presented pertaining to the specific work operations to be performed. The talks are presented by the foreman to his crew each week in meetings lasting for 5–15 min (Fig. 11). These sessions are carefully planned and the information is designed to change attitudes and develop safety consciousness in every type of employee. If this phase of a safety program is pursued regularly and faithfully, and if there is enthusiasm and interest on the part of supervision, the results will be substantial gains in employee safety performance. Many water companies throughout the nation are using this medium with gratifying results.

2. Six meetings are held each year for discussion of topics for the weekly meetings and to advise foremen on the most effective means of presentation.

3. An organized system of job instruction has been developed for new employees. It includes adequate training in use of tools, equipment, proper lifting methods, the use of safety equipment and materials, and any other phase of safety pertinent to the work the new employees will be doing. Proper instruction and an insistence upon adherence to established rules in the department's safety manual help the new employee to realize the importance of safety. The foremen are required to continue training new men in safe work practices for at least 6 months.

4. The foreman is required to assemble his crew after an accident occurs and discuss with them the cause of the accident, and how it could have been prevented. Quick dissemination of accident information is in itself enough to prevent an immediate recurrence. Timely information concerning an accident is carried by supervision to all other crews performing similar work.

5. Safety committees, composed of all levels of supervision, have been established. Their duties are to investigate all major accidents and determine the remedial action needed. This is one of the more useful points in a safety program, as it brings a greater number of supervisors into active participation. To neglect the investigative phase of the program is to leave the path wide open for recurrences of the same accident.

Fig. 12. Crew Safety Record Displayed on Truck

The sign not only helps to build crew morale, but it also promotes goodwill for the utility by openly displaying an interest in safety.

6. A signboard is mounted on the side of each truck (Fig. 12), showing man-days worked without a lost-time injury. The totals are changed daily.

This is of tremendous value; the sign is a daily reminder to the crew of its safety achievement, and it sharpens interest. When an accident does happen, it is disappointing to see the total return to zero. No small part of the effectiveness of this display is its public relations aspect.

7. In recognition of good safety practice, a plaque is awarded to each crew working a year without lost-time injury.

The sixth point of the program helps promote employee interest, and, in the seventh, their efforts are tangibly recognized in the presentation of the award.

Conclusion

Each water utility must have a definite, organized, and built-in program in order to reduce accidents. There is no shortcut to safety education. There are literally hundreds of activities, aids, and safety devices available to industry. Dozens of articles have been written on the subject. It does not really matter what method is used, as long as there is a method and a goal in the safety program.

Americans have always placed a high value on a human life. During World War II, in many instances, the cost of searching for and saving a single downed pilot involved hundreds of thousands of dollars. Everyone can recall some gallant rescue in which huge amounts of money were spent to save a single life. Industry has always unstintingly thrown valuable equipment and manpower into a rescue effort when needed. Such examples always demonstrate that the cost of safety is much less than the price of accidents.

In a safe operation the results are assured and future performance can be closely estimated. No company without a safety program can accurately estimate its cost of operation. Accidents, if allowed to continue unabated, can eventually undermine every phase of a company's operations.

In spite of industrial mechanization and the advance of automation, the workers of the water supply industry are more important today than ever before. Their operating experience and technical skill cost the industry hard dollars, and, when a worker is not on the job, it results in greater losses than ever before.

Water utilities are past the age of the *zanjero*. They need all of their manpower and all of their money, if they are to accomplish the challenging tasks that lie ahead. Any water utility can enjoy substantial reductions in cost of operation as the result of a well planned, integrated safety program. More important, it can enjoy an even greater reward—a reduction in human suffering and the elimination of the needless waste of valuable manpower.

Cross-Connection Hazards and Controls

William D. Shillinger and George G. Fassnacht

A paper presented on Feb. 5, 1959, at the Indiana Section Meeting, French Lick, Ind., by William D. Shillinger, San. Engr., Indiana State Board of Health, La Porte, Ind., and George G. Fassnacht, San. Engr., Indiana State Board of Health, Indianapolis, Ind.

INDIANA was among the first states to regulate cross connections. There is little doubt but that the Fort Wayne incident of 1923 was a motivating factor. In that year, river water used by an industry was pumped through a cross connection into the city drinking water system. At least 150 cases of typhoid and 22 deaths were attributed to the resulting contamination. On Jan. 9, 1924, the Indiana State Board of Health passed a regulation prohibiting any physical connection between a public water supply and a secondary supply from a surface source.

Only ten other states had such a regulation before May 1925, when AWWA held its annual conference in Louisville, Ky. During that meeting, the Fire Protection Division of AWWA passed a resolution against any physical connection between a public water supply and any other supply, except "with another potable public supply" or "with a potable supply which is regularly examined as to its quality" by those in charge of the public supply. It further urged each municipality to eliminate permanently all other connections.[1]

Unfortunately, it takes more than legislation to eliminate cross connections. Shortly after the Indiana regulation and the AWWA resolution had been made, an incident occurred at a meeting ground near Winona Lake that stressed the need for cross-connection control. A pump that supplied lake water to toilet facilities broke down, and a connection was made to the city water system. After the pump had been repaired, however, the cross connection was forgotten about. The subsequent typhoid epidemic resulted in more than 1,000 cases. Early in 1929, another typhoid outbreak occurred in an Indiana city after river water had been pumped into the city distribution system.

At the end of 1929, the Conference of State Sanitary Engineers, after reviewing the situation in the United States, went on record as opposing any cross connection between a potable water supply and an unapproved one. It was urged that state and local authorities control cross connections, and plumbing fixture manufacturers were asked to cooperate in eliminating the dangers of back siphonage.

Indiana Regulation

The Indiana regulation was revised in October 1931, to permit connections between a public supply system and a secondary system from other than a surface source, only under two conditions: either the secondary source had to be well located, properly constructed,

and—as evidenced by tests made at frequent intervals—up to public supply standards, or, if the only deviation from the above was a minor item of construction, the two systems might be separated by approved protective devices. The owner or operator of each public supply system in the state was to locate all existing connections with other supplies and report them to the board of health.

The last revision of the regulation was made in 1945. In addition to prohibiting any physical connection between a public supply and a secondary surface source, it required that a protective device be installed on all services, including fire lines, from the public supply to the property. Although it was not written into the regulation, a protective device was suggested for all service lines to factories using chemicals, even if no secondary supply is involved. The requirement that a secondary ground water source be frequently tested and approved if it was to be connected to a public supply through a protective device was deleted. The regulation still requires that owners and operators of public supply systems survey existing physical connections and report conditions to the board of health. They must further inspect and test all protective devices at 6-month intervals and repair all faulty devices immediately or sever the connection of the two systems. Moreover, they must not furnish any new service until they are certain that no provision of this regulation will be violated.

Cross-Connection Hazards

Some of the incidents that have occurred in Indiana since 1945 might well cause responsible water supply operators to be concerned.

In 1946, an industry used a well that supplied water which was too hard for factory needs. At that time, the municipal supply from the Ohio River had about 75 ppm hardness. Samples of water, analyzed because of complaints from residents of a limited area, disclosed a hardness of 400 ppm in the city mains. The subsequent investigation revealed that the industry used city water for its operations and then, sometime before its meter was read, pumped well water backwards through the meter in order to decrease the water bill.

In 1948, in a community supplying lime-softened, iron-free water, the appearance of red, hard water in one section of town caused the residents to complain. It did not take long to locate a factory from which well water was being pumped into the city system. The following year, unsatisfactory bacteriologic samples started an inquiry in another town. The water superintendent complained of hard, rusty water in just one section of the distribution system that was supplied with ion-exchange–softened water. Circumstantial evidence pointed to a factory whose plant engineer became indignant at the suggestion that his company was pumping water into the city mains. He was completely at a loss for words, however, when he was shown the meter running backwards at 30 gpm.

In 1950, a manufacturing plant complained of bad-tasting turbid water. Samples drawn from the office drinking fountain justified the complaints, but the water was not the same as that coming into the plant. A solvent used in a degreasing machine was found to have the same objectionable odor. It was not determined just how the solvent got into the water. It could have been from back siphonage through a

cooling coil or, more probably, from a pumping arrangement involving a waste sump below the degreasing machine.

Two years later, dark purple or black water appeared transiently at a few taps in a very limited area of a large city. The color appeared on three occasions, at the same time that pressure irregularities occurred in the system. A new, wooden, fire water storage tank had been erected on the roof of an industrial building in the area. It had replaced a tank that had almost rotted to pieces. The color probably was from tannin that had leached from the untreated new wood. Two check valves on the fire line were jammed with enough splinters from the old tank to allow reverse flow whenever the pressure in the city mains dropped 10 psi.

In 1955, chlorophenol tastes developed in a chlorinated well water supply. Most of the bad water, as determined by threshold odor samples, was in the vicinity of a factory. City water was used to fill the factory's fire reserve cistern and supply its sprinkler system. A jockey pump taking suction from the cistern kept 90 psi pressure on the sprinkler system. The cistern had an old tar lining and a half inch of oil floating on its surface. It was found that two gate valves and the brass-to-brass check valve between them leaked. After the valves were repaired, the objectionable odors disappeared. An approved double check system was installed as soon as the valves could be obtained.

Last year, at a new shopping center served city water, a butcher shop owner had a well drilled to supply his refrigerator compressors. The well did not provide enough water, so the butcher used some from the city supply. In this instance, the city water pressure was greater than that produced by the well pump. An investigation, made because of abnormally high meter readings in the butcher shop, disclosed an unintentional ground water recharge, which caused the butcher to discontinue the use of his well.

In the past, the board of health has had to rule against pumping well water through an industrial heat exchanger before it reached the city mains, and has had to prevent the pumping of water back into the municipal distribution system after it had passed through a residential heat pump. Recently, a consulting engineer asked for a ruling on the reuse of steam. He was designing a heating system for a large office building that would use steam purchased from a utility. In order to save on operating costs, and possibly to reduce the sewer service charge, he proposed to pump the condensate into the hot water pipes of the building. The request was refused.

This year, the state board of health received specifications for two hospital projects which call for pumping equipment and controls to apply an unspecified chemical to all the water entering the buildings. One of the hospitals is served from a municipal supply, the other has its own well. No protection or checks were proposed for the public supply. There was some indication that the chemical to be used might be a phosphate, but the board of health will give the proposal no further consideration until the chemical is specified. The application of chemical pumps brings to mind another potential hazard—namely, the cross connection of potable-water pipes to the

discharge side of condensate-return pumps or feed pumps for in-the-line treatment of makeup water for boilers.

The Indiana regulation concerns only the physical connections between public supplies and secondary sources. Current thinking on cross connections ranges from such interconnections to interconnections between *any* potable supply and a secondary source, and includes the potential hazards from industrial chemicals and back siphonage.

Protective Devices

In December 1958, the Joint Committee on Backflow Preventers published a report [2] that included a discussion of reduced-pressure, diaphragm-operated double check valves. The University of Southern California Research Foundation for Cross-Connection Control conducted laboratory and field tests of these devices. The conclusions of the foundation, quoted in part by the joint committee, state that the reduced-pressure backflow preventer actually furnishes as much protection as the air gap and may be used in its place, provided that an adequate testing and maintenance program is instituted to insure against defective operation. The device was further recommended for use on cross connections where health hazards exist.

There is some doubt whether these devices can be as effective in areas with freezing climates as they were in Southern California. Application of suitable mountings would be exceedingly difficult. Further requirements for satisfactory operation are passed over with the phrase "adequate testing and maintenance program." The initial test of the device is to be made within 90 days after installation, with subsequent tests at yearly intervals. A complete overhaul of the valve in place is to be made at least every 5 years. The discharge from the atmospheric port is to be visible to the operator at all times, or it should be inspected visually at least once a month.

The joint committee does not seem to be as sure of this device as is the research foundation. In their recommendations on the use of the device, the committee stated:

> Reduced-pressure backflow preventers can be used on potable-water connections to establishments maintaining an unapproved water supply (as might be obtained from a river, lake, harbor, creek, or unapproved well) or water from an approved source that has been used and thus become contaminated before reuse. This is a "second line of defense" at the meter, and no physical connection should exist in the establishment unless protected by a method or device acceptable to the local authority.

It is reasonable to assume, as the joint committee asserts, that the reduced-pressure backflow preventer offers more protection than the double check. Further, it can be accepted as a second line of defense, but it does not provide the complete protection needed. Certainly, it does not warrant a blanket approval.

Conclusions

The 1958 report presents many valid statements on the subject of cross-connection control: cross connections cannot be legislated out of existence; in large industrial plants, it is impossible to prevent the installation of unprotected cross connections; there is no check valve available that can be guaranteed not to leak; a testing and maintenance program is indispensable

to an effective plan for cross-connection control; and industry has the right to use to its advantage the water it buys, provided that no hazard is created. But the report must be read in its entirety, not as isolated statements, if its value is to be appreciated.

The fact still remains that there is no foolproof device to prevent contamination of a public water supply by backflow from a customer's property. Protection of the public supply is the joint responsibility of the board of health and the owner or operator of each water utility. No community can be exempt on account of size. One faulty connection in a small community can be as much of a hazard as a dozen faulty connections in a large city.

The water utility operator must be constantly alert to dangerous situations. He must get his plumbers oriented to the hazards involved and ready to cooperate. Backflow prevention devices must be tested at 6-month intervals and overhauled periodically. Even if all hazards cannot be eliminated, they can be held to a minimum.

References

1. Society Affairs. *Jour. AWWA,* 14:505 (Oct. 1925).
2. Joint Committee Report. Use of Backflow Preventers for Cross-Connection Control. *Jour. AWWA,* 50:1589 (Dec. 1958).

New Discount System for AWWA Publications

AWWA has adopted a coupon system that will enable members to obtain 20 per cent discounts, not only on AWWA books and manuals as at present, but also on standards and reprints. To take advantage of the discount, a member buys a book of AWWA Publication Discount Coupons having a total value of $10, for which he pays only $8. When he has occasion to order a publication, he simply encloses the appropriate number of coupons in payment. Coupons will be good until the end of 1965 and can be exchanged for cash without loss at any time till then.

As part of the new policy, AWWA will discontinue the present system of discounts for cash. Also, on orders for publications totaling less than $5, not accompanied by remittance in cash or coupons, a $1 handling charge will be added. The purpose of these steps is twofold: to increase the efficiency of service and to reduce the disproportionately high billing and accounting expense involved in handling small non-cash orders. Members who do not wish to buy coupons can, of course, avoid the handling charge by enclosing payment when ordering, but it is hoped that the ease and economy of using the discount coupons will be widely recognized.

The coupon system should prove of particular benefit to those members who must use official purchase orders and, therefore, in the past, were unable to obtain cash discounts because they could not make advance payment. By purchasing a coupon book they will be gaining the same 20 per cent discount as other members.

Orders for coupon books (at a price of $8 for each $10 book) should be addressed to AWWA Order Dept., 2 Park Ave., New York 16, N.Y.

Control and Elimination of Cross Connections

Panel Discussion

A panel discussion presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif.

Andrew T. Dempster

Director, Bureau of San. Eng., Dept. of Health, Detroit, Mich.

THE degree of interest in control measures for the elimination of cross connections has been mainly dependent on the number of reports of waterborne diseases attributed to these connections. The absence of any current mention of cross connections in the press or in technical journals might suggest that the problem has been solved. Unfortunately, it has not. There are more possibilities of cross-connection hazards today than ever before, because of the more extensive use of potable supplies in increasingly complex industrial and commercial processes and equipment. For example, cross-connection hazards have increased with the growth of the air-conditioning industry, which needs to conserve or reuse possibly contaminated cooling water.

Many states have attempted to solve their cross-connection problems by legislation, making it illegal to maintain any cross connection between safe and unsafe water supplies. A few states supervise and protect existing cross connections with double check valves but have made it unlawful to construct a new cross connection. There is some doubt, however, with regard to the protection afforded by the mere existence of a law.

Almost every law enforcement official concerned with water supply has found cross connections that may have been operative at one time. Some officials may even know of an operative cross connection that has exposed the public to toxic chemicals, particulate matter, or pathogenic organisms. But if such exposure did not result in an alarming incident, the matter probably was not given any publicity. This may partly explain the dearth of published articles on the problem.

Backflow Prevention Devices

Sometimes, illegal or inadvertent cross connections are made in spite of laws and periodic inspections. A barrier, such as a double check valve assembly, installed in all potable-water lines entering areas that are also supplied with contaminated water or hazardous chemicals, has been required in some cities and states to limit the extent of backflow.

For instance, during World War II, double check valves were installed at water outlets on seacoast harbor piers after operative cross connections discovered on ships resulted in the contamination of water systems on shore and on other ships using these same outlets. A shortcoming of the double check valve is that it makes difficult the detection of leaks or backflow. To overcome this difficulty, a device was designed incorporating double check valves with an automatic drainoff valve

between them. The device was further improved to cause the pressure zone between the check valves to be lower than the pressure upstream. This was done by spring-loading the check valves and automatic drainoff valves. This improvement made possible the detection of leaks. At the same time, it effectively prevented backflow.

Inasmuch as the reduced-pressure backflow prevention device has been available for more than 15 years, enough time has passed to make possible an evaluation of its performance. In 1953, a joint committee was appointed by AWWA and the Conference of State Sanitary Engineers to study and report on all kinds of backflow prevention devices. A report[1] was published in 1958. Specific recommendations were made with regard to the basic parts of a backflow preventer, friction losses, danger of breakdown, frequency of inspections, and location and installation of the devices. The committee reported that the backflow preventers had been reliable, and they recommended that the devices be approved for installation on water service connections or at other points acceptable to local authorities. They also recommended that inspection programs should be continued or instituted as essential factors in a good cross-connection control program, and that testing procedures and installation standards be continuously improved by the establishment of a standing committee for cross-connection control. Despite the progress made in eliminating them, cross connections still remain a threat to the health of the public.

Reference

1. Joint Committee Report. Use of Backflow Preventers for Cross-Connection Control. *Jour. AWWA*, 50:1589 (Dec. 1958).

Ray L. Derby

Prin. San. Engr., Dept. of Water & Power, Los Angeles, Calif.

Three points regarding cross-connection control merit discussion: (1) air gap separation as compared to backflow prevention devices, (2) standards for backflow prevention devices, and (3) a proposed manual of recommended practices for backflow control.

Air Gap Separation

The Los Angeles Department of Water and Power has realized for many years that, theoretically, air gap separation is the best protection against backflow. In most instances, however, it is not economical. Part of the customer's bill for water is based on its delivery under the normal pressures of a system. Air gap installations bring this pressure down to zero, and, usually, the customer must install a receiving tank and a pump to redevelop the pressure. To insure a constant supply of water at adequate pressure, often more than one pump must be ready for use in case of emergency. Because of this added expense, the air gap is frequently bypassed by the customer, sometimes in such a way that the bypass can be discovered only by very close inspection. Under such conditions, not only is the protection afforded by air gap separation completely eliminated, but also the situation is actually worse than before, because the city assumes that the system is safe when it is not. This does not mean that air gap separations are not permitted in Los Angeles. The city has a large number of them. They are frequently recommended in places where they may be readily inspected and economically installed, with a reasonable expectation that they will not be bypassed.

Standards

There is a need for a comprehensive set of standards for backflow prevention devices and a well planned testing and maintenance schedule. The Los Angeles Department of Water and Power entered into a contract with the University of Southern California Research Foundation for Cross-Connection Control and the university's engineering center. A comprehensive set of standards was prepared for double check valves and backflow prevention devices operating under the reduced-pressure principle. Included with the standards were recommendations as to where the devices could appropriately be used with safety.

Testing and Approval

The department, in cooperation with the Los Angeles Health Department, the Research Foundation for Cross-Connection Control, and industry, established minimum requirements for the testing and approval of the devices. In brief, a device is tested and evaluated in the foundation's laboratory. If it successfully passes the laboratory tests, a maximum of three devices are installed for a 6-month test period. At the end of this period, the device is again evaluated by the department and the foundation. If no defects are observed, a *certificate of provisional approval* is granted, and the manufacturer is permitted to sell the device with the understanding that if serious defects occur within a 3-year period, the approval may be rescinded. If the devices are operating satisfactorily at the end of 3 years, they are given a *certificate of full approval.*

A device that meets the standards is tested by the water purveyor after it is installed by the customer. If it performs satisfactorily, it is put on a 1-year test schedule. A customer is notified by letter that a test on a certain device is required. He has 30 days from the time the notice is issued to have the test made, service the device if necessary, and forward a certified copy of the report to the water and power department. Customers using an air gap separation are required to submit a certified annual report that the air gap separation has not been bypassed or otherwise made ineffective.

Other than the first test and occasional spot checks made by the water purveyor, all tests are performed by certified testers at the customer's expense. These testers are required to take an examination to show that they are properly equipped and qualified to test and repair the devices. The certification of testers is carried out under a regulation of the Los Angeles Health Department.

The device is tested annually until it shows faulty operation, at which time it must be repaired. Immediately after repair, and again 3 months later, the certified tester will check the device. If it is operating satisfactorily, it goes back on the annual schedule. If it is still faulty, it will have to be repaired again and remain on the quarterly test schedule until it is operating satisfactorily. Otherwise, it must be replaced.

Manual of Recommended Practices

Two or 3 years ago, an organized group of water utility personnel in Southern California appointed a committee to prepare a manual of recommended practices for backflow control. The committee, composed of three members, has patterned its work after the standards of AWWA, which are not mandatory but recommended practices that most water purveyors are glad to accept and follow as standard practice. The manual will consist

of twelve sections concerning the following:

1. Objectives
2. Cross-connection control policy, based on the regulations of the state department of public health
3. Responsibilities of the health agency, water purveyor, customer, and certified tester, based on state health regulations
4. Definitions of terms that need clarification
5. Various cross connections and water uses that may endanger a public water system
6. Legal considerations with regard to noncompliance with regulations, failure to protect against cross connections, and improper testing of devices
7. Recommended practices for cross-connection control
8. Mechanical devices that have been approved and testers of backflow prevention devices who have been certified by the Los Angeles Health Department
9. Equipment needed and the proper procedures for testing backflow prevention devices
10. Specifications for backflow prevention devices, both double checks and reduced-pressure devices, as developed by the Research Foundation for Cross-Connection Control and the University of Southern California Engineering Center
11. Sample letters and forms that might be useful to the inspector, the purveyor, or the health department
12. Bibliography and various case histories.

Work on the manual is nearing completion, and it has been tentatively submitted to other groups in Orange and San Diego counties for suggestions and recommendations. When agreement is reached by the various groups in Southern California, the manual will be submitted to the state department of public health for further recommendations—after which it is hoped that this manual will be adopted for statewide use by the California Section of AWWA.

The majority of those whom the committee has contacted have been very enthusiastic about the manual. There are many health inspectors, sanitarians, and plumbing inspectors in the southern part of the state who are eagerly looking forward to the issuance of such a manual, for they lack the experience necessary to cope with cross-connection programs. It is believed that the manual will aid inspectors and water purveyors and, at the same time, help standardize cross-connection control procedures.

E. Jerry Allen

Asst. Supt., Water Dept., Seattle, Wash.

All operators of water supply systems will agree with the basic principle that the surest way to protect water in a distribution system is to eliminate all physical connections between a potable supply and a nonpotable supply. USPHS drinking water standards for 1946 indicate that among the sources of contamination are dual supplies, bypasses, cross connections, interconnections, and backflow connections. It is further established that a health hazard refers to any operating condition relative to water supply, including any device or water treatment practice, that is a threat to the welfare of the consumer. The definition of a water supply system states that it includes the works and auxiliaries for collection, treatment, and distribution of water from the source of supply to

the free-flowing outlet of the ultimate consumer. There has thus been established a criterion with regard to unsanitary conditions throughout a supply system.

Areas of Responsibility

USPHS standards also specify that the supply system in all of its parts shall be free from sanitary defects and health hazards, and that all such conditions and hazards shall be systematically removed at a rate satisfactory to the reporting agency and the certifying authority. The standards further require a continuing program for the detection of health hazards before a public water supply may be approved. It is true that in the applications of the standards, the federal government has seen fit to assign responsibility to the water purveyor from the source of the supply to the connection at the customer's service pipe. From this connection to the free-flowing outlet of the customer, the responsibility is assigned to the owner of the property served and to the local governmental agency having legal jurisdiction. Even though the federal government may establish these divisions of responsibility, certification of a supply can come only after the elimination of sanitary defects and health hazards from source to free-flowing outlet.

Washington Requirements

All state departments of health prohibit unprotected cross connections. The state of Washington, for example, prohibits cross connections whether they are controlled by automatic devices or by hand-operated mechanisms. Washington defines a cross connection as any physical arrangement whereby a public or semipublic water supply system is connected directly or indirectly to any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device that may contain contaminated water, sewage, or other wastes capable of spreading contamination as a result of backflow. A strict interpretation of USPHS standards and Washington requirements leaves no doubt that a potable supply must be separated from all potential sources of contamination.

In 1909, legislation passed in Washington specified that any person responsible for a facility supplying water for public or private use who is found guilty of impairing the water supply shall be guilty of a gross misdemeanor. The concept of liability of the water supplier for permitting cross connections to exist and the need for insuring that wholesome water is supplied for domestic purposes is supported by the case of Aronsen *v.* City of Everett.[1]

The question of accepting a reduced-pressure backflow prevention device as a means of eliminating cross connections is unresolved. It is known that such a device requires a continuing test and maintenance program; it is also known that there are very few laboratories capable of performing the basic tests for all sizes of such devices, which must be approved and periodically tested. In addition, required forms must be submitted and filed.

Although the responsibility for protecting both the customer's piping and the public supply system may be that of the health authorities, the ultimate legal liability rests with the water supplier. Such liability cannot be assigned to the customer. The supreme court of Washington, as well as the courts in other states, is firmly committed to the opinion that when a municipality operates a water system

and sells to private customers, it is acting in a proprietary capacity and may be considered comparable to a private corporation with regard to liability.

In the progress report of the Joint Committee on Backflow Preventers,[2] it is recognized that the air gap generally affords maximum protection against backflow. The committee also recognizes that an air gap, as well as a mechanical backflow preventer, must be regulated and frequently inspected.

Summary

The final responsibility for the quality of water delivered to the consumer rests with the officials in charge of a supply system. In some states, this responsibility is specified by law. Some states also specifically prohibit the use of mechanical devices for guarding against backflow and for protecting against cross connections. Because of this prohibition, it does not seem wise either to encourage or condone the use of mechanical backflow preventers. Moreover, inasmuch as the air gap is believed to provide maximum protection against backflow, it is not in the best interests of water purveyors to condone mechanical devices as a substitute.

References

1. *Aronsen* v. *City of Everett* (Wash.) 136 Wash. 312, 239 P 1011 (1925).
2. Joint Committee Report. Use of Backflow Preventers for Cross-Connection Control. *Jour. AWWA,* 50:1589 (Dec. 1958).

Henry J. Ongerth

San. Engr., State Dept. of Public Health, Berkeley, Calif.

The December 1958 report of the Joint Committee on Backflow Preventers [1] is now receiving much attention, for it contains new information on cross-connection control. There are, however, indications that this report is a controversial one. It is significant that the Conference of State Sanitary Engineers adopted the following resolution after considering the report:

> The Conference of State Sanitary Engineers receives this report but does not endorse it, for the reason that many of its members have indicated that some of the principal recommendations contained in the report are in direct conflict with current policy or regulations in their states.

Definitions of Cross Connection

Some of the objections to this report may stem from misunderstandings that have resulted because of the differences in definitions of cross connection contained in the 1942 and 1958 reports. The 1942 report of the Committee on Cross Connections [2] states:

> A cross connection may be defined as any physical connection by means of which water may flow between a public or private potable supply and a nonpotable supply or an unapproved supply.

In the context of this report, the definition refers to an interconnection between a domestic system and some other supply—generally a fire-fighting or an industrial water supply—from streams or wells. The 1942 report further states:

> Potential hazards may be grouped into three main classes: (1) pollution of the general distribution system as a result of improper construction or faulty operation; (2) pollution by backflow connections or through interconnections with plumbing fixtures, waste water disposal systems, or equipment conveying or containing harmful liquids or nonpotable water or water subject to pollution; and

(3) pollution through cross connections with other supplies. As the first two potential hazards constitute the subject of investigations by other committees, the Committee on Cross Connections has confined its activity and attention to the third of these hazards.

The definition given in the 1958 report states:

> A cross connection shall mean any connection between a public potable-water supply system or a private consumer's potable-water piping system and any other source or system whereby it is possible to introduce into any part of the potable-water system any water or substance other than the intended potable water from which the system is primarily supplied.

This is a considerably broader definition than was used in 1942. Some confusion arises from the later definition because it is not clear what is intended by the phrase "source or system." The latter part of the definition seems to imply that the phrase is meant to include those hazards listed in Item 2 of the 1942 report—namely, pollution by backflow connections, plumbing fixtures, or equipment containing nonpotable water subject to pollution.

These differences in definition lead to confusion in the discussion of Recommendation 1 of the 1942 report, which, in essence, is that no new cross connections should be permitted between potable supplies and nonpotable or unapproved supplies. The 1958 report states that Recommendation 1 should not apply to cross connections with industrial process waters. By definition, the 1942 committee expressly excluded this type of hazard. Comments in the 1958 report, made under the headings "Assignment 5—Applicability" and "Analysis of the Backflow Problems," are also confusing because of the vagueness of the recent definition.

The following comments fall into two categories: reduced-pressure backflow preventers, and the general objectives of cross-connection control and the applicability of various backflow prevention devices.

Reduced-Pressure Devices

The description and illustration of the reduced-pressure device in the 1958 report would have been more informative had drawings of the internal details been presented. Inasmuch as only two companies * manufacture this device, diagrams from both might have been used. Reduced-pressure devices include two spring-loaded, poppet-type check valves arranged in series. The chamber established between these two check valves is automatically opened to atmosphere by a spring-loaded, diaphragm-actuated relief valve when certain pressure relationships exist. These features of the device are not clearly described in the report.

The portion of the report concerning "Assignment 3—Clogging and Breakdown" would have been improved if an analysis had been made of factors that may lead to the failure of the springs and diaphragm in the device. In particular, it would be valuable to have information concerning the action of corrosive water or heavily mineralized water on these parts. Further, no attempt was made to evaluate the performance of poppet check valves as compared with swing check valves. The discussion concerning the opening of the relief valve to atmosphere is inadequate. During normal functioning of the device, the spurting of water

* Backflow Engineering & Equipment Co., Los Angeles, Calif., and Crane Co., Chicago, Ill.

from this opening may occur during sudden major changes of pressure in the device. (One of the important elements of hydraulic-mechanical design is to prevent too frequent spurting due to minor pressure changes.) In some places, this spurting may be objectionable; therefore, consideration should be given to device location and provision for drainage. Further, because spurting may be objectionable, or for other obscure reasons, in some instances the outlet has been capped. When this occurs, the device provides protection equivalent to that from a double check valve assembly. This relief valve opening must be designed with hydraulic capacity that will permit escape of as much water as may leak past the downstream check valve. This is a necessity in the design, and it should have been so mentioned in the report. Los Angeles has established standards on capacity of discharge from relief valves—for example, 20 gpm for a 2-in. device.

The report states: "Should the compression spring or diaphragm in the differential relief valve fail, the device will still operate to prevent backflow." Additional information should have been provided on the performance of the device in case of minor leakage in, or major failure of, this diaphragm. Further, only general statements of field performance of reduced-pressure devices are presented. Details of field test results would have been much more informative and would have given readers an opportunity to draw their own conclusions. Testing reduced-pressure device requires special equipment and knowledge. The report should have discussed these.

Records of field performance concern the reduced-pressure devices manufactured by two reputable organizations under patent rights due to expire in about 2 years. More stress should be placed on the necessity of adequate specifications for satisfactory performance for new makes of valves that may be manufactured in the future. Further, AWWA should seriously consider the development of a standard.

An important phase of the report relates to "Assignment 5—Applicability." In particular, the use of the reduced-pressure device in lieu of air gap separation is recommended. The committee also recommends the use of reduced-pressure devices in lieu of double check valve assemblies, including applications where double check valves are used against system or low-order public health hazards. There is no doubt that the reduced-pressure backflow preventer provides more protection than the double check valve assembly, but it does not provide as much protection as the air gap. The report presents two arguments in favor of the use of the reduced-pressure device in lieu of the air gap: (1) the customer has the right to the pressure available from the domestic water system, and (2) the air gap may be bypassed. The customer does suffer economic loss because it is necessary to repump when utilizing air gap separation in lieu of some other backflow prevention device. The argument that the customer has a right to delivery of water at line pressure may also be employed against the use of the reduced-pressure device where it is used in place of the double check valve assembly. Head loss through a reduced-pressure device is many times that through a double check valve of similar size, operating under similar flow conditions. The argument that

air gap does not provide foolproof protection is only partially valid. It is widely recognized that the degree of protection of any backflow prevention device is a combination of the physical characteristics of a backflow preventer and the program of testing and maintenance of the unit. No backflow prevention device can be relied on to give continuous protection without a routine periodic testing and maintenance program. This is true of air gap protection and of the reduced-pressure backflow preventer, as well as of a double check valve assembly. The California Department of Public Health, which has a program of inspecting the installations of air gap separation at sewage treatment plants, has found that a routine inspection program insures the most protection, but that, without routine inspection, bypasses may be installed.

Some comments in the report about the applicability of reduced-pressure backflow preventers are difficult to interpret because of the complexity of the report and because the definition of cross connections is indefinite. It is not clear whether the committee considers that a reduced-pressure backflow preventer must be installed at the meter where plumbing hazards exist within the premises. If this is meant by the report, a strong dissent is hereby registered. Reduced-pressure devices are also recommended at the service to industrialized piping systems for plants where fluids are handled in nonpressure systems. Further, the report states that double check assemblies are not suitable for use "where positive protection against backflow is essential for prevention of . . . system hazards." In both instances, the double check valve assembly generally will provide a high enough degree of protection.

Superior-Pressure Devices

The superior-pressure backflow preventer is also discussed. The committee does not recommend this device because it may allow leakage to occur on low-pressure differentials. The nature of backflow during low-pressure differentials should be examined in detail. Moreover, the committee's recommendation concerning the superior-pressure device should be revaluated in the light of the findings.

Protection Against Hazards

The 1958 report states that the policy for selecting the appropriate device is that the degree of protection should be commensurate with the degree of hazard. A complete understanding of the applicability of devices cannot, however, be accomplished by policies stated in general terms. It is believed that misunderstandings can be avoided only when specific examples of hazards are cited in conjunction with devices proposed for protection. The 1958 report should be expanded or modified in this regard. The following are specific examples of protection against hazards:

The 1942 report recommends against the interconnection of public sources of supply with dangerous private sources. This objective is a necessity because of the hazard of interconnection and because the consequences of backflow are so objectionable. Such conditions necessitate a vigorous and prompt program involving the elimination of interconnections by the creation of air gaps.

A lesser hazard exists at premises where private wells, not under public

health supervision, are used for domestic purposes—for example, in private homes, industrial plants, schools, and resorts. In these places, protection against interconnection and possible backflow is a desirable objective, but the hazard is small and the need for correction not urgent. Double check valve assemblies may be used for protection.

Other lesser hazards include the many system hazards that occur when nontoxic materials, such as beer, brines, soft drinks, and starch solutions, are handled under pressure within industrial premises. Double check valve assemblies (internally weighted and with bronze working parts) will provide adequate protection of the system. As check valve failures are few when an adequate program of testing and maintenance is employed, instances of backflow will be rare. At the worst, failure will permit only small quantities of liquid to flow back into the community system.

Another lesser hazard exists in industrial plants where toxic chemicals—plating solutions, for example—are handled in gravity tanks. The hazard here results from the possibility of back siphonage through submerged inlets in tanks. Whether or not meter protection is needed depends upon case-by-case evaluation of the possibility that negative pressures will occur in the supply line, the relative elevations of tanks and mains on plant premises, and the size and general character of the plant. When meter protection is deemed necessary, a double check valve assembly will generally provide an adequate degree of protection.

When water is supplied to office buildings, hotels, commercial buildings (such as department stores), hospitals, or apartment houses where plumbing hazards may exist, the major objectives should be internal correction, because the greatest hazard is to the occupants of the premises. Meter protection at such premises may not be justified. Studies may be desirable concerning potential backflow from such premises to community water mains.

In industrial plants where toxic or hazardous chemicals are handled under pressure, reduced-pressure devices or air gaps are necessary.

Water service to sewage treatment plants and sewage pumping stations should be provided only through air gap separation.

Water supply to piers and dock areas may be protected either by air gap separation at the service connection to the pier, or by reduced-pressure devices at the water service outlets at the pier, or both.

Calculated Risks

In the section on "Analysis of the Backflow Problems" in the 1958 report, it is stated that:

> The common goal in the control of cross connections is to protect the water supply and the system from the harmful effects of pollution or contamination in *any* amount. The protective device or method used to attain that goal should offer the utmost safety in this respect.

Cross-connection and potential backflow hazards today constitute the greatest dangers to a public water supply. It is doubtful, however, that absolute protection and safety should be sought. Public health programs widely recognize the fact that some elements of risk cannot be completely eliminated. In all public health programs an attempt is made to balance the cost of

protection with the hazards, and, in some instances, calculated risks must be taken. The challenge to both water utility and public health personnel is to determine which hazards are of such significance that they must be corrected, and which ones are of lesser significance and may remain uncorrected indefinitely. The committee statement regarding absolute protection is apparently the basis for the definition of an acceptable or approved backflow prevention device. This definition states:

> An acceptable or approved backflow prevention check valve shall be drip-tight and constructed to assume rapid and positive closure under all conditions of service. It shall permit no leakage in a direction reverse to normal flow, and when seated shall permit no leakage in the intended direction of flow when the inlet pressure is a predetermined minimum above the outlet pressure.

Attention is drawn to two phrases in this definition: "shall be drip-tight" and "when the inlet pressure is a predetermined minimum above the outlet pressure." The first phrase gives rise to a question: What is the public health significance of minor leakage—less than 0.1 gpm, for example—under various circumstances? A study of this question seems desirable. The implications in the second phrase relate to some of the apparent differences in the performance of double check valves in different areas of the United States. In most areas, double check valves are tested against full back pressure; in some areas, however, they are tested against low back pressure (2–5 psi). Procedures for testing should be evaluated through a study of the possibility of backflow caused by back siphonage resulting from low or negative pressures in supply mains.

Back Siphonage

A large number of back siphonage hazards exist on consumers' premises. This type of hazard is a low-order threat to the community water supply. In many instances, it is likely that no protective device will be needed. When needed, protection of the community supply will generally be satisfactorily accomplished by the installation of a double check valve assembly. Back siphonage, though a low-order hazard to the community supply, may constitute a relatively high-order hazard to the occupants of the premises. Two courses of action are necessary to reduce this internal hazard to a tolerable level, neither of which takes precedence over the other: (1) an adequate plumbing ordinance, along with adequate enforcement of the ordinance; and (2) water purveyor programs to reduce to a minimum those events that result in abnormally low or negative pressures in street mains. Much useful information, and a necessary basis for intelligent evaluation of protection needed, may be obtained from a study of occurrences of low or negative pressures in community distribution systems. Studies should also be made of the records of interruption of flow due to main breaks, planned shutdowns for maintenance and repair, and emergency shutdowns. Pressure records for given systems, in given locations, should be studied.

Conclusions

Any one of the three backflow prevention devices discussed in the report will provide full protection as long as the device continues to function as it was intended to. The difficulty with air gap separation is that the unit may be bypassed. A reduced-pressure

backflow preventer must be properly constructed, installed, and maintained for high-level protection. It has the unique advantage of giving external indications when it is not functioning properly. Improper use and maintenance of this device may lead to its failure. The double check valve assembly, for effective performance, must be properly designed, constructed, and maintained. It should be built with bronze working parts, if not entirely of bronze. The design approved by the Factory Mutual Engineering Division has resulted in good performance. If there is no maintenance of a double check valve assembly, there will ultimately be no protection.

Thus a major problem in backflow prevention is the critical need for a regular maintenance program. Each unit installed must be regularly tested and maintained. It is essential, therefore, that the demand for the installation of backflow devices should be carefully limited to those really needed for protection. Some water purveyors feel that the testing program should be handled by the water user or by an approved private testing agency. Nonetheless, it is proposed that the water purveyor accept the responsibility for the regular testing of devices and that the cost of this program be passed on directly to the customer on whose service connection such a device is installed.

Too much time has passed since the last report on cross-connection control. Strong support should be given to the recommendation that a permanent committee on cross-connection control be established.

References

1. JOINT COMMITTEE REPORT. Use of Backflow Preventers for Cross-Connection Control. *Jour. AWWA,* 50:1589 (Dec. 1958).
2. COMMITTEE REPORT. Cross-Connection Control. *Jour. AWWA,* 34:17 (Jan. 1942).

Study of Materials to Replace Copper-Base Alloys in Meter Manufacture

Joint Discussion

A joint discussion presented on Jul. 15, 1959, at the Annual Conference, San Francisco, Calif.

Introduction and Summary—*Herbert F. Barrett*

A paper presented by Herbert F. Barrett, Chairman, Tech. Committee, Water Meter Industry Joint Research Program, and Sales Mgr., Buffalo Meter Co., Buffalo, N.Y.

AT the 1946 Annual Conference of AWWA, one of the important subjects discussed was what new materials of construction would be used by the water supply industry in the postwar world. The answer at that time was "Not many." Since then the question has repeatedly been raised by manufacturers seeking competitive improvement or lower cost. It has also been raised by customers seeking lower prices.

Joint Venture

No one water meter manufacturer could successfully promote a new material for water meter construction. General acceptance would be necessary if the new material were to be incorporated into AWWA standards, which would have to be done if the new material were to be widely used. The expense of the research required would also be unduly burdensome for any one company. Therefore, the water meter manufacturers of the United States 3 years ago jointly undertook a unique research program that was to affect the entire industry. The companies joining in this program, listed alphabetically, were Badger Meter Manufacturing Co., Buffalo Meter Co., Worthington Corporation, Hersey Manufacturing Co., Neptune Meter Co., Rockwell Manufacturing Co., and the Calmet Division of Well Machinery and Supply Co.

These companies believe they are more interested than any of their customers in progressive developments in water meters. They know that present meters are not perfect; the better they become, however, the easier business life becomes, and the better the needs of the industry and its customers are served. The Armour Research Foundation of Chicago was, therefore, engaged to conduct a study of materials for the replacement of copper-base alloys in the manufacture of the outer casings of water meters, primarily of the small sizes. The program was devoted to materials for outer housings only, and had two goals: (1) to ascertain whether any satisfactory and less expensive substi-

tute for copper alloys for meter housings might be found for ordinary use, and (2) to investigate whether there might be any emergency substitute for copper-base alloys to which the industry could turn, should the need ever arise.

that could be used with good results. The plastics that might be found best under peacetime conditions might be even more scarce than copper in an emergency. The research for peacetime improvements did, however, center on plastics.

TABLE 1

Explanation of Code for Materials Tested

Code Letter	Composition	Trade Name and Manufacturer
A	acrylonitrile methylstryene	Cymac 201 }
B	polymethylstyrene	Cymac 400 }
C	fabric-filled melamine formaldehyde	Cymel 3020 } American Cyanamid Co.
D	glass-filled melamine	Cymel 3136 }
E	acrylonitrile styrene	RMD-4511; Bakelite Co.
F	rigid polyvinyl chloride	Exon 4023 } Firestone Plastics Co.
G	high-impact polyvinvyl chloride	Exon 4051 }
H	polyvinyl chloride	Geon 8750; B. F. Goodrich Chemical Co.
I	polyether	Penton; Hercules Powder Co.
J	medium-impact polystyrene	Dylene 80 }
K	high-impact polystyrene	Dylene 800 } Koppers Co.
L	glass-filled polystyrene	Fibertuf }
M	acrylonitirile styrene butadiene	Cycolac H; Marbon Chemical Div., Borg-Warner Corp.
N	high-impact, rubber-modified, polystyrene	Lustrex 89 } Monsanto Chemical Co.
O	medium-impact polystyrene	Lustrex LHA }
P	high-impact polyvinyl chloride	Marvinol NR-7058 } Naugatuck Chemical Div.,
Q	polyvinyl chloride	Marvinol NR-7080 } U. S. Rubber Co.
R	acrylonitrile styrene	Tyril 767; Dow Chemical Co.
S	polyacetal	Delrin; E. I. du Pont de Nemours & Co.
T	polycarbonate	Lexan; General Electric Co.
U	high-impact, modified styrene	Kralastic HTHT; Naugatuck Chemical Div., U. S. Rubber Co.
V	glass-filled styrene	Styrene G; Fiberfil Corp.
W	hard rubber	

This research program was carried on for 2½ years at a total cost of nearly $75,000. Armour Research Foundation was given complete freedom to investigate any materials that might accomplish the general aims.

The research on wartime substitutes centered, of course, on metals other than copper and on protective coatings

This research project terminated a few weeks before the San Francisco conference. The participating manufacturers asked Richard C. Reichel of Armour Research Foundation who has been prominently connected with the program, to present a summary of the work and findings. This is presented as the second half of this discussion.

So far as the writer is aware, this is the most detailed study that has been made under scientifically controlled conditions. The study made privately four years ago by the Engineering Research Institute of the University of Michigan for Buffalo Meter Co., which was reported to AWWA at its 1956 meeting, covered, in a less complete way, a laboratory study of the various metallic couples now being used in various water meters.

Results of Study

The portion of the Armour study concerning possible emergency replacement materials for meter housings confirmed that bronze is by far the most suitable material. Certain plastic and enamel coatings on cast iron appeared promising under test conditions—conditions which, however, could hardly be duplicated in actual meters. In any present design of meter there are some points exposed to water where the protective coating terminates. At such points corrosion develops. It is the opinion of the manufacturers that there is no current design that would permit such coatings to be reliable for main casings, although they have long been used for frost bottoms in some meters.

There is also a substantial uncertainty as to whether the more desirable plastics for coating on cast iron would actually be available in a national emergency.

More than half the Armour investigation concerned the possible use of plastics for replacement of bronze under peacetime conditions. Of the 40 plastics tested, 75 per cent were eliminated either because of high water absorption, poor dimensional stability, low tensile strength, poor molding properties, or similar undesirable characteristics.

Reichel's report shows that only Materials *S* and *T* (Table 1) were still in the running at the conclusion of the 1958–59 series of tests. These had shown good resistance to water absorption and general dimensional stability when immersed. In the bursting test, the particular casings which had been prepared from Material *S* burst at 600 psi. The mold used had been made by one of the meter manufacturers, and had been specially modified to get high strength. Despite this, the plastic housing burst at a pressure at which a conventional bronze housing would be completely undamaged. Although further design changes could probably increase the bursting strength of Material *S*, it will never approach bronze. Whether it will be strong enough for reliable use has yet to be determined. This will require that two or three manufacturers make molds for meter housings of improved design and then make field tests of a quantity of meters for a couple of years. No tests have yet been made on freezing or on combination of heat and high pressure.

The casing made of Material *T* had a toughness that resisted bursting, but it yielded and leaked instead. Inasmuch as a meter housing may be subject to repeated water hammer shocks, as well as freezing strains, it is not certain how a housing of this plastic would stand up under such conditions or whether it would develop permanent leaks. Freezing tests and tests for bursting under heat also have not been made.

The investigation has thus far been limited to technical aspects. At present, the cost of the two most satisfactory materials is quite high, and the

percentage of imperfect castings appears to be high, even with the best of molding. It is very uncertain whether there would be any economic advantage at present in the use of either of these materials for plastic housings, even if all technical difficulties were solved.

Conclusion

The Reichel report is interesting both for the information it contains and as evidence that the meter manufacturers are giving the most careful study to the subject of improved materials. If progress appears slow, it is because the industry cannot afford any mistake on such an important part of a meter.

When considered from both the technical and the economic aspects, it appears certain that, as of today, there is no reasonably adequate substitute for bronze. Even if there were, a large percentage of the public utilities would probably continue to demand bronze, as long as it remains available.

Further study will, of course, be made by the various manufacturers to follow up the more promising developments of the 1958–59 study. Whether anything will be offered to the customers within the next 5 years is open to question. Certainly, the author does not see any possibility of a successful replacement of bronze in meter housings in less than that time. Depending upon the time required for advance testing in actual service, the time might be considerably longer. The joint-venture agreement, which made this research program possible, is continuing, and the means for any further studies which are believed valuable are, therefore, available.

——Armour Foundation Report—*Richard C. Reichel*——

A paper presented by Richard C. Reichel, Assoc. Chem. Engr., Armour Research Foundation, Chicago, Ill.

Because the cost of copper-base alloys is constantly rising and because copper is indispensable and scarce during emergencies, water meter manufacturers have been induced to seek substitute materials. Therefore, companies in the water meter industry have collectively supported an investigation of polymeric materials and various metals as possible replacements for bronze in meter manufacture.

The objectives of the research program, which was conducted at Armour Research Foundation, were:

1. To determine the materials that are as good as or better than bronze as a water meter housing in one or more of the following: cost (of material or manufacture), availability (particularly in times of national emergency), and quality of service in the field

2. To determine, with the assistance of the water supply industry, the suitability of the proposed materials for water utility service.

Plastics for Molded Housings

The plastics to be evaluated were selected on the basis of the manufacturer's data on physical properties, heat distortion point, water absorption, dimensional stability, and ease of molding. Under normal conditions water meters are subject to water pressures of up to 150 psi and water temperatures near 80°F. In addition, the possibilities of increased pressure due to

water hammer and of increased temperature due to steam backup were considered. The selected plastics were evaluated by determining the effect of water immersion on their dimensions and physical properties. For convenience in references to the materials studied, they have been coded by letter as shown in Table 1.

phenolics, unmodified styrenes, acrylics, and polyethylene are not presented, as these materials were eliminated from consideration early in the program. The data in Table 2 are for sheet samples $\frac{1}{8}$ in. thick. Thinner samples of the same materials gained water more rapidly and the water absorption rate of many samples leveled

TABLE 2

Effect of Water Immersion on the Physical Properties of Plastics for Molded Meter Housings

Material	Water Absorbed *per cent**			Tensile Strength *1,000 psi*				Flexural Strength *1,000 psi*		
	10 Days	100 Days	500 Days	Initial	100 Days	300 Days	600 Days	Initial	200 Days	400 Days
A	0.40	0.44	0.45	8.3	8.3	8.2		14.5	14.3	14.1
B	0.024	0.019	0.017	5.9	4.8	4.75		9.3	9.4	8.8
C	0.99	2.5	2.75	7.3	7.3	7.3	7.3	11.5	12.5	12.5
D	0.24	1.05	1.28	5.7	4.0	3.7	3.7	12.0	8.0	10.0
E	0.27	0.30	0.308	9.3	9.4	9.5	9.8	15.2	16.4	16.0
F	0.10	0.34	0.475	7.5	7.6	7.7	7.9	13.7	13.4	13.7
G	0.155	0.53	0.80	6.3	6.5	6.7	6.9	11.5	11.5	11.6
H†	0.15	0.23	0.27	8.1	8.2	8.4	8.7	12.9	13.4	13.6
I	0.023	0.059	0.076	5.65	5.6	4.6	5.5	7.0	6.9	6.9
J	0.15	0.40	0.49	4.7	6.6	5.5	6.1	11.5	11.5	12.0
K	0.04	0.14	0.18	4.0	3.8	4.0	4.7	10.0	9.4	9.1
L	0.21	0.47	0.50	5.6	4.7	4.6	5.0	12.6	11.7	12.0
M	0.51	0.99	1.21	4.8	4.5	4.8	4.8	8.5	8.0	7.9
N				4.9	4.9	5.0	4.9	11.6	12.5	12.2
O				4.9	4.5	4.6	4.5	12.8	12.1	12.0
P				7.7	7.4	7.1		11.5	11.2	11.0
Q				9.3	9.1	9.0		15	13.4	13.1

* Dry weight.
† Thickness was 80 mils.

Immersion Tests

Sample materials in the form of sheets, tensile bars, or molded and machined discs were immersed in distilled water or Chicago tap water for periods up to 22 months. Examinations and tests for water absorption, dimensional changes, tensile strength, flexural strength, and surface defects were carried out at selected intervals. Table 2 is a summary of data that illustrated the observed trends. Data for nylons, off after an initial rapid increase. The weight increase for thicker samples would also be expected to level off after a longer time. The data indicated less than 0.2 per cent water absorption in 500 days for polymethylstyrene, high-impact polystyrene, and a polyether. Materials which absorbed more than 1 per cent of water and had a slow approach to equilibrium were the filled melamines and an acrylonitrile-styrene-butadiene copolymer.

Tensile Strength

During the initial screening program, the effect of water immersion on the ultimate tensile strength and elongation of 40 plastics was determined. The test samples were strips, $\frac{3}{16}$ in. wide, cut from sheets that had been stored under distilled water at room temperature. Measurements were carried out with a tensile-strength-testing machine * at a cross head speed of 1 ipm. The data in

* Instron; a product of Instron Engineering Corporation, Quincy, Mass.

TABLE 3

Tensile Strength and Elongation of Polymer Bars Immersed in Chicago Tap Water

Immersion Time *months*	Tensile Strength* *psi*	Elongation* *per cent*	Immersion Time *months*	Tensile Strength* *psi*	Elongation* *per cent*
Material *E*			Material *T*		
0	11,110	7.9	0	8,340	12–13
1.0	11,750	7.7	1.0	8,620	12.6
2.8	10,940	7.6	2.8	8,150	12.4
5.0	11,540	8.1	5.0	8,360	12–13
7.4	11,560	7.8	7.4	8,340	12.5
11.4	11,930	8.2	11.4	8,680	12.1
Material *R*			Material *H*		
0	10,380	6.3	0	7,700	6.4
1.0	10,150	5.5	1.0	8,180	6.7
3.2	10,250	6.2	2.7	7,890	7.2
5.7	10,180	5.7	5.2	8.060	6.6
7.2	10,310	5.5	6.7	8,100	6.1
9.5	10,090	6.4	9.0	8,380	7.3
Material *S*†			Material *M*		
0	9,760		0	4,590	7.5
1.0	10,000		1.0	4,660	7.1
2.7	9,720		4.7	4,290	7.5
5.2	9,660		6.9	4,460	7.8
6.7	9,740		9.3	4,480	7.3
9.0	9,970		13.3	4,680	7.8
Material *V*			Material *U*		
0	13,390	4.0	0	7,740	7.0
1.0	12,080	3.5	1.0	8,000	6.7
4.7	11,130	3.4	2.8	7,200	6.7
6.9	11,580	3.8	5.0	7,450	7.0
9.3	11,520	3.4	7.4	7,680	6.7
13.3	11,180	3.4	11.4	8,030	7.1

* Yield point.
† Stress-strain curve is similar to that of cast iron; no yield point was, therefore, obtained.

Table 2 show that tensile strength changed very little as a function of water immersion time for most of the materials. The strength of the vinyl chlorides actually increased by 7–10 per cent in 600 days. The materials that were eliminated early in the program, with the exception of polyethylene, all showed a decrease in tensile strength with immersion time.

Five materials were tested after storage in both distilled water and in Chicago tap water, with essentially the same effect on tensile strength, indicating that the type of water has little influence on the physical properties of the immersed material.

During the second half of the program, standard injection-molded tensile bars of eight materials, including five plastics not previously evaluated, were immersed in Chicago tap water and tested after periods up to 13 months. Table 3 shows that little change in tensile strength occurred during the period of testing, with one exception; Material *V*, with the highest initial tensile strength (13,400 psi), showed a decrease to approximately 11,500 psi during the first 5 months.

Three materials had been tested previously in the form of strips cut from sheets. Observed differences between the test results for cut strips and for molded bars may be due to differences in sample geometry, the method of preparation, or actual material variations.

Flexural Strength

The flexural-strength data in Table 2, obtained with the testing machine mentioned above, show changes of less than 10 per cent in 400 days of immersion for all the materials tested except a glass-filled melamine composition, which showed a decrease of 17 per cent.

Machined Discs

Molded discs of eight plastics and hard rubber were machined to a uniform size approximately 3.05 in. in diameter and 0.118 in. thick. Three discs of each material were placed in each of two baths of Chicago tap water maintained at 80°F and 110°F respectively. The weight and diameter changes are presented in Table 4. No direct comparison should be made between the water absorption data for disc samples and for the previously evaluated sheet samples, because it was evident that the material formulations were not the same. For example, the sheets of Material *A* were of the unmodified natural material, whereas the discs were molded from a black material. Differences between water transmission rates through machined surfaces and molded surfaces may explain some of the results, but it is certain that material variations were a major factor in some instances. Curves plotted from the data for the discs indicated that Materials *A*, *E*, *I*, and *T* approached equilibrium in 4 weeks; Materials *H*, *R*, *S*, *V*, and *W* were still absorbing water after much longer periods.

Surface Defects

Samples were examined for evidence of crazing, cracking, blistering, swelling, and color change caused by extended water immersion.

Medium- and high-impact grades of polystyrene developed surface blisters. Blistering did not occur on all samples of these materials, however, and appeared to be associated with certain color pigments.

TABLE 4

Water Absorption and Dimensional Stability of Machined Discs Immersed in Chicago Tap Water*

Immersion Time *weeks*	Water Absorbed *per cent*†		Diameter Increase *0.001 in.*	
	at 80°F	at 110°F	at 80°F	at 110°F
Material *V*				
0.5	0.10	0.17	0.4	2.2
1.0	0.13	0.19	0.7	2.4
2.0	0.16	0.23	1.1	2.8
4.0	0.19	0.27	1.4	3.0
6.0	0.20	0.28	1.6	3.0
10.0	0.21	0.32	1.8	3.2
16.0	0.22	0.38	1.8	3.0
Material *T*				
0.5	0.22	0.21	1.7	4.0
1.0	0.27	0.37	1.8	4.2
2.0	0.33	0.40	1.9	4.2
4.0	0.37	0.40	2.0	4.2
6.0	0.37	0.40	2.0	4.2
10.0	0.37	0.40	2.0	4.2
16.0	0.37	0.40	2.0	4.2
Material *S*				
0.5	0.31	0.60	6.0	11.3
1.0	0.56	0.79	6.8	12.2
2.0	0.61	0.96	9.0	14.6
4.0	0.77	1.10	10.7	15.7
6.0	0.85	1.14	11.4	16.5
10.0	0.93	1.20	12.8	17.9
16.0	1.00	1.21	13.5	18.1
Material *E*				
0.5	0.37	0.60	2.0	3.8
1.0	0.50	0.70	2.4	4.1
2.0	0.60	0.77	3.2	4.9
4.0	0.68	0.79	3.3	4.9
6.0	0.69	0.80	3.5	5.1
10.0	0.695	0.81	3.7	5.2
16.0	0.695	0.82	3.8	5.3
Material *A*				
0.5	0.38	0.60	1.8	3.8
1.0	0.52	0.72	2.2	4.0
2.0	0.62	0.78	3.0	4.5
4.0	0.70	0.80	3.2	4.9
6.0	0.71	0.82	3.4	4.9
10.0	0.72	0.835	3.5	5.0
16.0	0.725	0.845	3.5	5.2
Material *R*				
0.5	0.35	0.55	1.7	3.2
1.0	0.42	0.62	2.0	3.4
2.0	0.56	0.72	2.5	3.7
4.0	0.64	0.74	2.6	3.7
6.0	0.65	0.75	2.9	3.9
10.0	0.655	0.76	3.0	4.0
16.0	0.66	0.77	3.2	4.1
Material *H*				
0.5	0.07	0.13	0.7	2.8
1.0	0.08	0.17	0.9	3.1
2.0	0.13	0.26	1.3	3.6
4.0	0.18	0.31	1.4	4.3
6.0	0.22	0.37	1.5	4.7
10.0	0.27	0.42	1.6	4.9
Material *I*				
0.5	0.009	0.03	0.3	2.5
1.0	0.012	0.040	0.4	2.5
2.0	0.022	0.049	0.5	2.7
4.0	0.030	0.050	0.65	2.8
6.0	0.038	0.066	0.7	2.9
10.0	0.040	0.070	0.8	3.1
Material *W*				
0.5	0.04	0.07	0.5	3.0
1.0	0.06	0.10	0.7	3.1
2.0	0.08	0.16	0.8	3.2
4.0	0.11	0.19	1.0	3.4
6.0	0.14	0.24	1.2	3.7
10.0	0.18	0.32	1.3	3.9

* 3-in. diameter.
† Dry weight.

Several of the filled phenolic materials also developed surface blisters. As a class, the phenolics developed the most severe surface defects with blistering, swelling, and color changes predominating.

Molding and Evaluation

Meter housings were molded from several plastics that appeared to represent the most promising of those considered. Selections were made on the basis of maintained high physical properties. Housings of Materials *E* and *V* exhibited lower burst strengths than were indicated by hoop stress calculations. The low burst strength of Material *V* was attributed to the stripping of threads and to the presence of molding weld lines. The housing could be redesigned to eliminate the need for threads; but the weld lines, unless eliminated, will be a detriment to obtaining satisfactory housings. It is believed that the poor test results with Material *E* were caused by poor molding and high stress concentrations at the threaded bolt sections. Burst strength data are presented in Table 5.

Housings of Material *S* had burst strengths that averaged more than 600 psi for the housing design tested. This strength would be sufficient to resist normal operating pressures of 150 psi with a safety factor of four (approximately the pressure at which standard meter frost bottoms are designed to fail).

Meter housings of Material *T* did not break under test. A series of clamping devices were utilized to hold the frost bottom in place, but each housing swelled sufficiently under pressure to allow water to escape momentarily.

TABLE 5

Burst Strength of Polymer Meter Housings

Housing No.	Burst Strength psi	Remarks	Housing No.	Burst Strength psi	Remarks
Material *E*			Material *V*		
1	450		1	275	Threads pulled out of bolt holes
2	250	Split at two sections	2	300	Threads pulled out of 2 bolt holes
3	260	Split at two sections	3	220	Threads pulled out of 2 bolt holes
4	330	Longer bolts used; split at three sections	4	275	Threads pulled out of 2 bolt holes
5	310	Longer bolts used; split at two sections	5	280–300	Threads pulled out of 2 bolt holes
6	325	Steel plate used on bottom with two additional clamps	6	320	Steel plate used on bottom with two additional clamps; split at stud; bolts pulled out
7	250	Steel plate used on bottom; split in half	7	210	Steel plate used on bottom; split longitudinally
Material *S*			Material *T*		
1	610	Split at each bolt section	1	*	Ears of frost bottom failed at 550 psi
2	600	Bolt section split	2,3	*	Different frost bottoms, gaskets,° and O rings used; leaked around bottom of housing; 750 psi highest pressure recorded
3	680	Pressure applied rapidly; multiple breaks appeared			
4	580	Pressure applied very slowly			
5	725	Pressure to 680 psi applied, O ring extruded twice			
6	610	Split at three bolt sections			

* Could not be determined owing to leakage at pressures in excess of 600 psi.

Water leakage usually occurred at approximately 600 psi, but in one housing a pressure of 750 psi was attained before leakage occurred. Leakage at high pressures would not, however, affect the usefulness of the housing when normal pressures were resumed.

Time did not permit evaluation of the resistance of molded housings to water hammer, hot water, and water freezing. Owing to delays in obtaining the test materials, the 2-year program expired before these tests could be made.

Metals as Substitutes

Another phase of the program was to evaluate several metals as substitute materials for the bronze in water meter housings. The bronze that is normally used is an ideal metal for this use in that it has excellent casting, machining, and other fabrication properties, adequate strength and ductility, and is extremely corrosion-resistant in most types of water. Its main drawback is the possible restriction of its use during national emergencies. The main factors governing the choice of metals to be tested were ease of fabrication, cost, and availability of raw materials. This research was chiefly concerned with determining the corrosion resistance of metals that filled those requirements.

Test Procedures

Fourteen identical spool assemblies of various test specimens were installed in water lines under actual flowing conditions throughout the United States. The assemblies consisted of samples of cast iron, bronze, and three types of aluminum, coupled and uncoupled, coated and uncoated. Each spool contained sixteen samples.

The spools were placed in 6-in., galvanized-iron water chambers fitted with galvanized-cast-iron flanges, galvanized nipples, and bronze valves. All test samples were installed for a year under conditions of constant immersion and intermittent flow. No samples were exposed to heat.

Results

Only small differences were observed in the corrosiveness of the various waters. The amount of corrosion products produced by various waters was much less significant than were the relative corrosion rates for different types of test specimens. Therefore, no breakdown of water quality data was made. The results of corrosion tests on twelve materials are given below:

1. *Bronze coupled to cast iron coated with black glass enamel.* The iron was rusted along the edges at breaks in the enamel, and the enamel was discolored on most of the faces. Protection of the iron by the enamel depended upon the continuity of the coating, especially at the bronze-iron junction.

2. *Bronze coupled to cast iron coated with white glass enamel.* The iron was rusted at the iron-bronze junctions in all samples, and there were numerous pinhole defects in the coating. Again protection of the iron depended on the continuity of the coating.

3. *Bronze coupled to cast iron coated with polyethylene.* No rusting or corrosion was noted, except at the uncoated iron-bronze junction.

4. *Bronze coupled to cast iron coated with polyether.* No rusting or corrosion was noted, except at the uncoated iron-bronze junction.

5. *Bronze coupled to cast iron coated with hard nickel (applied by a replacement reaction).* The coatings were blackened in many cases, and there were numerous undermined spots. At points where the coating had worn away there was heavy rusting.

6. *Bronze coupled to cast iron coated with electrolyzed chromium.* The iron samples were the same as the nickel-coated ones.

7. *Bronze coupled to 356 aluminum coated with nickel.* Most of the coating was gone and there were large, blackened, unpitted areas. The coating tended to flake at the sites of corrosion attack and there was extensive undermining.

8. *Bronze coupled to 356 aluminum coated with electrolyzed chromium.* The aluminum was extensively covered with carbonate deposits and showed numerous, isolated deep pits containing loose corrosion products.

9. *Bronze coupled to uncoated aluminum.* Three types of aluminum were tried; in each instance the aluminum was badly pitted and covered with heavy carbonate deposits.

10. *Uncoupled bronze.* This bronze held up very well, with only slight increases in weight.

11. *Uncoupled black cast iron.* All the specimens were heavily rusted and scaled. The weight losses were among the highest.

12. *Uncoupled aluminum.* Three types of aluminum were tried; in each instance the specimens were badly pitted with heavy carbonate deposits.

Galvanized chambers and nipples were found to be in good condition. Evidence of zinc loss and of carbonate deposits was found in all of the chambers and nipples.

Conclusions

Of the various metals evaluated in this program, bronze was definitely the most resistant to corrosion by potable water. The replacement of all or part of the bronze in water meter housings with cast iron or 43, 214, or 356 aluminum should definitely be avoided. Electrolyzed chromium or nickel coatings on aluminum or cast iron were also completely unsatisfactory as corrosion inhibitors.

Protective coatings of glass enamel, polyethylene, and polyether were satisfactory on cast iron when complete coverage of the base metal was attained. Plastic-coated specimens were slightly superior to enameled ones, but this was probably due to the technique used in applying the coatings.

The investigation of the effects of water immersion at normal temperatures indicated that, so far as this factor is concerned, specific plastic materials can be used as metal substitutes. Naturally, substitution must be regulated by design considerations. Results of burst strength tests on housings of Material *S* were encouraging, particularly as the strength was in excess of 600 psi for the design tested. The dimensional changes in Material *S* may may be a detriment; it is possible, however, that dimensional problems can be taken care of by proper design.

The results obtained with Material *T* were very encouraging; however, the leakage due to swelling under extreme pressure should be studied further. This material is the most promising from three viewpoints: (1) its high heat distortion point, (2) its high tensile strength, and (3) its excellent toughness as indicated by high resistance to impact. If it proves to be a problem, leakage of water under high

pressures may be reduced or eliminated by proper design. For example, a retaining ring could be used, or a thicker bottom section.

The investigations indicate that Materials *S* and *T* are presently the most promising plastics to replace bronze in water meter housings. Whether they are sufficiently good to be used in meters depends on many performance and design factors not evaluated by Armour Research Foundation. Economic factors were not considered. The detailed findings, along with recommendations for future work, have been referred to the manufacturers for their further study and decisions.

Acknowledgments

Grateful acknowledgment is made to the meter manufacturers for permission to publish this paper. The author is especially indebted to W. S. Baker, T. Van Rossum, H. T. Francis, and J. M. Miller for valuable advice, suggestions, and assistance given throughout the course of this work.

Reprints Available

Reprints of the following articles, published in the JOURNAL during recent months, will be available from the Association in small quantities, at the prices noted, until the present stock is exhausted. Order by reprint number and author's name from: Order Dept., American Water Works Assn., Inc., 2 Park Avenue, New York 16, N.Y. A handling charge of $1 will be added on all orders under $5 unless accompanied by payment in US or Canadian funds or in AWWA Publication Discount Coupons.

Reprint No.	Author	Title	Issue of JOURNAL	No. of Pages	Price per Copy
R807	BARTHOLOMEW, SILVEY	Odor Control With Copper	Apr 58	8	20¢
R808	MARTIN, WHITE	Vehicular Safety	Apr 58	7	20¢
R809	AWWA POLICY	Reservoir Recreational Use	May 58	2	15¢
R812	TASK GROUP REPORT	Artificial Recharge	Jul 58	7	20¢
R813	THOMAN & JENKINS	1956 USPHS Survey	Aug 58	7	20¢
R814	METZIGER, GULLANS, STAFF REPORT	Fluoride Availability	Aug 58	10	25¢
R815	WEBB, HICKMAN, ALLEN	Safety Programs	Aug 58	18	30¢
R818	PANEL DISCUSSION; WOLMAN	Water Rights Law	Oct 58	18	30¢
R819	CONWAY	Fluoridation Law	Oct 58	7	20¢
R820	TASK GROUP REPORT	Domestic Water Use	Nov 58	11	25¢
R821	PANEL DISCUSSION	Plastic Pipe	Nov 58	14	25¢
R824	COMMITTEE REPORT	Backflow Preventers	Dec 58	32	45¢
R901	PANEL DISCUSSION	Chlorine Residuals	Feb 59	19	30¢
R902	SEEGER & WALSH	Extension Problems	Mar 59	9	25¢
R904	FTC DECISION	"Water Conditioner" Claims	Jun 59	3	15¢
R905	KOENIG	Economics of Saline Water Conversion	Jul 59	18	30¢
R906	EASTMAN	Bond Issue Campaigns	Sep 59	16	25¢
R907	INGRAM & MOORE	Fluoridation in Major Cities	Sep 59	16	25¢
R910	PIPER	Model Water Law	Oct 59	6	20¢
R911	FAUST	Plastic Pipe Standards	Oct 59	4	15¢

Effect of Valve Operation on Water Hammer

S. Logan Kerr

A paper presented on Jul. 16, 1959, at the Annual Conference, San Francisco, Calif., by S. Logan Kerr, Cons. Engr., Flourtown, Pa.

SEVERAL articles published in the JOURNAL, including those by Goit,[1] Angus,[2] and others, have described studies of the action of valves in pipelines. McPherson [3] has described the results of an extensive research program on the flow characteristics of butterfly valves.

In a previous article [4] the author outlined the theoretical approach to the problem. A graphical procedure was given for the computation of water hammer pressures with uniform and with variable rates of flow control. In this article, however, a series of actual problems will be discussed and field test data shown.

The importance of the effect of valve action on water hammer cannot be emphasized too strongly. The surge pressure resulting from valve closure is a function of the maximum *rate* at which the flow is changed and not the total change of flow in the total time.

Effect of Valve Size

The first example that is considered here is a shutoff valve at the discharge end of a very long pipeline. The capacity of the pipeline is 20,000 gpm, and the initial design called for a 22-in., electric-motor-operated gate valve in a pipe of 31-in. diameter. The valve stem was to move at a uniform rate.

Precise calibration data were available on the valve and, when applied to the problem, gave the relations shown in Fig. 1. For the first 50 per cent of the closing stroke, the flow was hardly affected, the next 10 per cent of stem travel reduced the flow by about 4 per cent. The travel from 40 to 30 per cent of open still let over 90 per cent of the full flow pass through the valve.

The control was effective from 20 per cent travel to zero, during which time 75 per cent of the flow was cut off. The high rate of change in velocity could have caused the surge pressures to exceed greatly the design rating of the pipe.

Another analysis was made on the use of a 16-in. valve with the relationships shown in Fig. 2. The last 30 per cent of stroke cut off 75 per cent of the flow, and surge pressures were substantially reduced. The final solution, however, was dual-speed operation, and a more uniform variation of flow rate was obtained.

The results of an actual test, made on a different project but with the same general conditions, are shown in Fig. 3. Measurements were made under carefully controlled conditions, and the time of the opening stroke was measured from the instant the control button was pushed. A new element, "dead" time, was thus introduced which further complicates the problem.

It can be seen that 75 per cent of flow was reached in about 30 per cent of the total opening time. It should

also be noted that 20 per cent of the latter was "unseating time" and not effective in controlling flow. The net effective time is thus only about 12 per cent of the total. The solution was to lengthen the time of travel and release the pressure much more slowly than before.

approximation based on an *equivalent* rate of change of flow gave 195-ft pressure rise.

This latter approximation has brought out another term, the "effective time" of valve stroke. In the example given this would be 40 per cent of full travel, or the time at which the

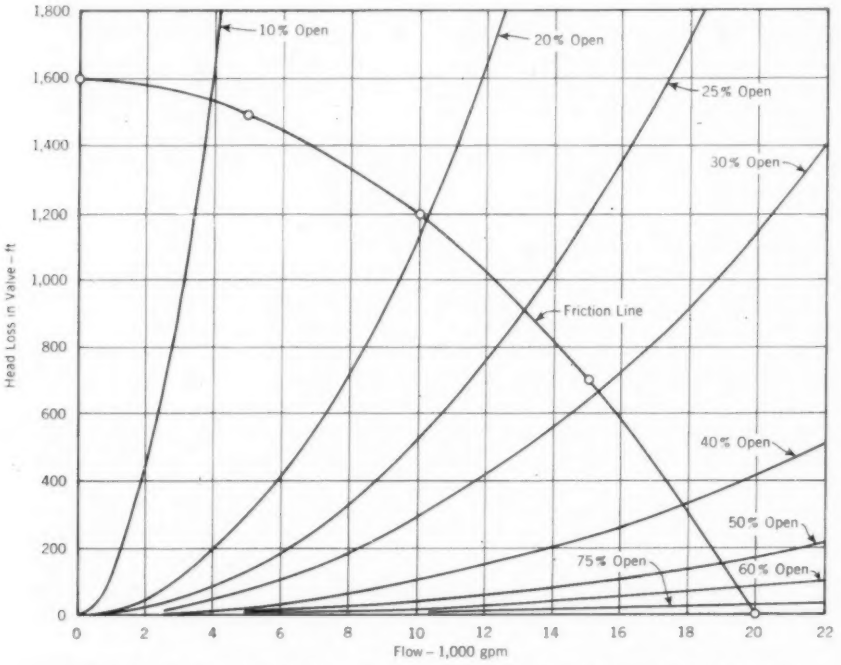


Fig. 1. Effect of Valve Position on the Relationship of Flow to Head Loss in a Long Pipeline

Data are for a 22-in. gate valve. The pipeline was 31 in. in diameter.

Effective Time of Stroke

In an article previously referred to,[4] test data on a large, motor-driven gate valve and a comparison of the water hammer pressures for an assumed *uniform* rate of change of flow (60 ft) and the *actual* rate of change of flow (210 ft) were given in graphs. An

valve should close to give the uniform rate of change in flow at the maximum rate attained at any point in the range from the fully open to the fully closed position.

In this article and in another article by the author,[5] curves of flow versus valve stem travel have been drawn

from the data of Goit.[1] These are shown in Fig. 4 for three types of valves tested in place. The tangent to the maximum slope of the curve for flow as a function of stem travel (assumed to be uniform with respect to time) gives the effective time.

"Effective time" can be defined in terms of total stem travel time as follows: $T_E = fT_T$ in which f is the ratio of the total stroke resulting from the tangent to the maximum slope of the flow calibration line, and T_E and T_T are the effective time and the total time, respectively.

available on the flow rates of valves at intermediate positions. It is suggested that the manufacturers should remedy the situation.

Much emphasis has been placed, and quite wrongly, on the cross-sectional areas at intermediate valve positions. The coefficient of discharge varies widely over the stroke, however, and depends upon the type of valve and the conditions under which it is to operate.

Three sets of tests have been selected to illustrate the relationship between flow and valve position. All

TABLE 1

*Effect of Nonuniform Flow Cutoff on Pressure Rise**

Valve Type†	Estimated Pipeline Constant, K	Calculated Pressure Rise *per cent*‡	Valve Factor, f	Net Effective Time, T_E *units* (N)	Actual Pressure Rise *per cent*‡	Ratio of Actual to Uniform Pressure Rise
Gate (3)	0.18	17.5	0.13	0.65	100	5.7
Gate (4)	1.63	12.0	0.39	1.96	42	3.5
Cone (4)	1.63	12.0	0.49	2.33	33	2.8
Globe (4)	1.63	12.0	0.52	2.58	29	2.4
Cone (5)	4.53	16.0	0.50	2.50	48	3.0
Cone (6)	0.17	17.8	0.35	1.75	54	3.0
Butterfly (7)	1.93	17.3	0.21	1.05	98	5.8

* To allow for nonuniform cutoff rates, one may find the total time (Tr) required to maintain the pressure rise at calculated pressure rise and divide by the valve factor (f).
† Numbers in parentheses refer to figures in which the tests are illustrated.
‡ Instantaneous pressure rise.

A range in effective time of 40–50 per cent of the total time is evident. The effect on water hammer pressures is obvious, as the flow would actually be cut off in half of the stem travel time or less.

Check Valve Tests

In analyzing a number of pumping installations for hydraulic and surge conditions, it has been necessary to have accurate data on the flow characteristics of the pump check valve. It is surprising how little information is

three were made in the field and the check valve was used to throttle the discharge. These tests, referred to below as Tests 1, 2, and 3, are illustrated in Fig. 5, 6, and 7, respectively.

Test 1

The check valve (described in Fig. 5) was gradually throttled while the pump continued to run. Measurements were taken of the flow and of the pressures on both sides of the valve. The slope of the curve of flow versus stroke varied, and three differ-

ent values are shown. No allowance for seating, unseating, or "dead" time was included, as only the plug rotation position was recorded.

The high rate of change of flow near the closed position was critical and resulted in an effective time of 45 per cent of the rotation time alone and about 35 per cent when open-position unseating time and "dead" time were included.

Test 2

In Test 2 (described in Fig. 6) the reverse rotation of the pump was being checked, and the discharge was not

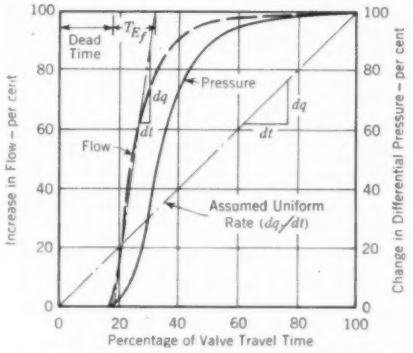


Fig. 3. Relationship of Discharge Flow and Differential Pressure to Valve Travel Time

Data are for an 18-in. gate valve.

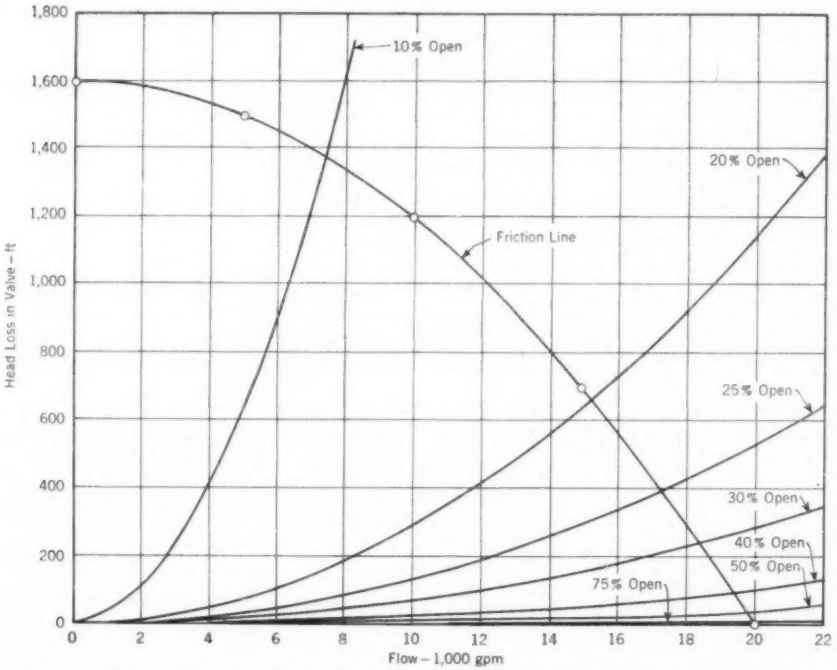


Fig. 2. Effect of Valve Position on the Relationship of Flow to Head Loss in a Long Pipeline

Data are for a 16-in. gate valve. The pipeline was 31 in. in diameter.

measured because the meters were not adjusted to measure backward flow. With plug rotation and pressure as the index, effective time was 35 per cent of the total time. If the "dead" time and unseating time in the open position had been included, the effective time would have been reduced to about 25 per cent of the total elapsed time for closure.

Test 3

Test 3 (described in Fig. 7) is similar to Test 2, but for totally different valve and pumping conditions. The effective time T_E was of the order of 20 per cent of the total closure time. As there was no unseating time, only the "dead" time in the valve controls should be added. The change in the effective closure time is negligible.

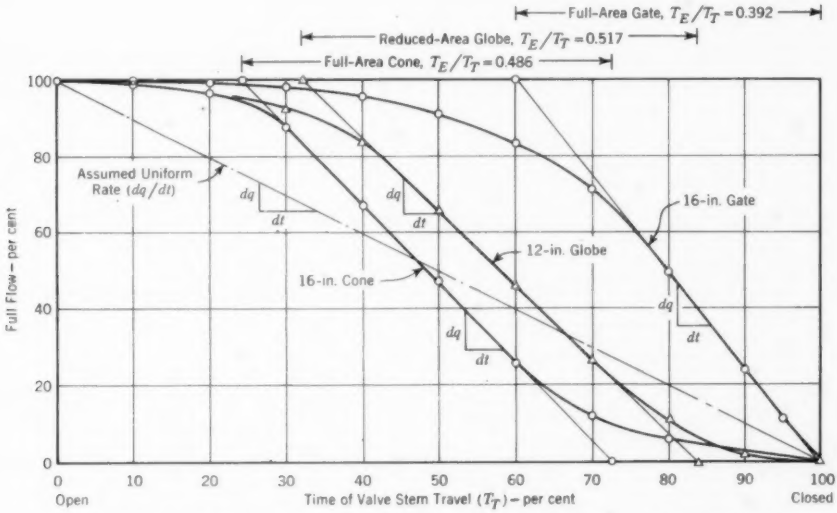


Fig. 4. Effect of Valve Stem Travel Time on Flow for Three Different Valves

The tangent to the maximum slope of the curve for flow as a function of stem travel (assumed uniform with respect to time) gives the effective time, T_E.

It should be noted that the full rated speed in reverse was reached when the plug was only 50 per cent rotated, and that practically no increase in speed resulted during rotation from the 60 per cent open to the fully open position. This is to be expected, as manifold pressures are approached on the pump casing at or near the half-open position of the plug.

Use of Effective-Time Term

In Fig. 8 pressure rise is plotted against the effective time (T_E) expressed in water hammer time units of $\frac{2L}{a}$ sec, in which L is the length of a gravity line and a is the velocity of the pressure wave in the pipe. The normal line should have a pipeline constant of 5.0 or less, and discussion is therefore confined to that curve.

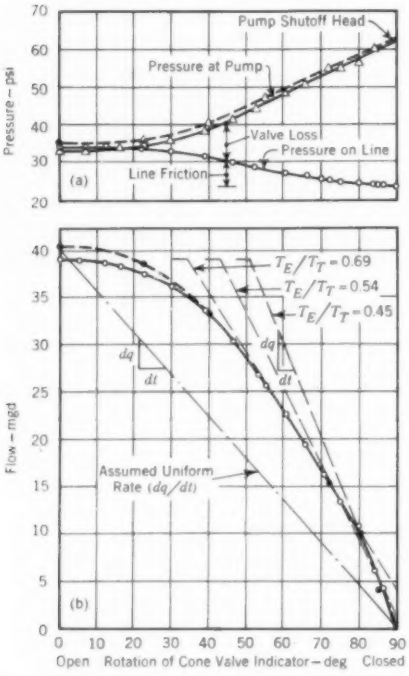


Fig. 5. Calibration of 30-in. Cone Check Valve in 5,000-ft Pump Discharge Line (Test 1)

Part (a) gives the relationship of pressure to rotation of the cone valve indicator; Part (b) gives the relationship of discharge flow to rotation of the cone valve indicator.

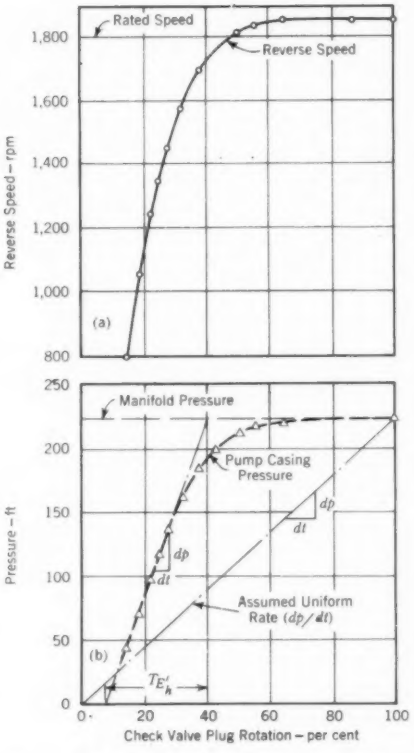


Fig. 6. Calibration of 10-in. Cone Valve to 25,000-ft Pump Discharge Line

Part (a) gives the relationship of pump reverse speed to check valve plug rotation; Part (b) gives the relationship of pump casing pressure to check valve plug rotation.

When $T_E = N = \dfrac{2L}{a} \leqslant 1$, the condition of instantaneous water hammer results. This is shown as 100 per cent in Fig. 8 for all values of the pressure rise, K.

If $T_E = 2N$, the pressure rise ($K = 5.0$) drops to about 65 per cent of instantaneous-surge values. For $T_E = 3N$, the pressure rise is only 40 per cent of the instantaneous surge; at $T_E = 5.0$, it approaches 15 per cent of maximum.

From these simple relations, and with a critical water hammer time $\left(\dfrac{2L}{a}\right)$ of 10 sec, the effective time becomes, for $N = 5$: $T_E = 50$ sec. On gravity lines it is usually safe to assume a factor (f) of $\frac{1}{3}$ to $\frac{1}{2}$; the total time would then be 100–150 sec. It is this total time, T_T, that should be given in specifications and in instructions for setting the piston or valve

stem stroke to keep the pressure rise within design limits.

Numerous variations in controls are possible, such as dual-speed operation and other means of increasing the effective time with respect to the total time. It must always be remembered, however, that it is the effective time, T_E, that determines pressure rise.

Table 1 gives the estimated pressure rise data for the types of pipelines shown in Fig. 3–7. It is assumed that they are gravity lines, and that closure at uniform rate of change in flow is made in five units of time ($T_T = 5N$).

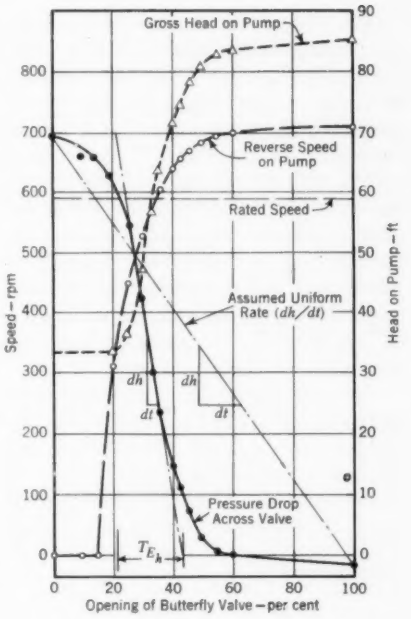


Fig. 7 (right). Calibration of 42-in. Butterfly Valve in 1,600-ft Pump Discharge Line

Effective closure time was of the order of 20 per cent of total closure time. As there was no unseating time, only dead time in the valve controls should be added.

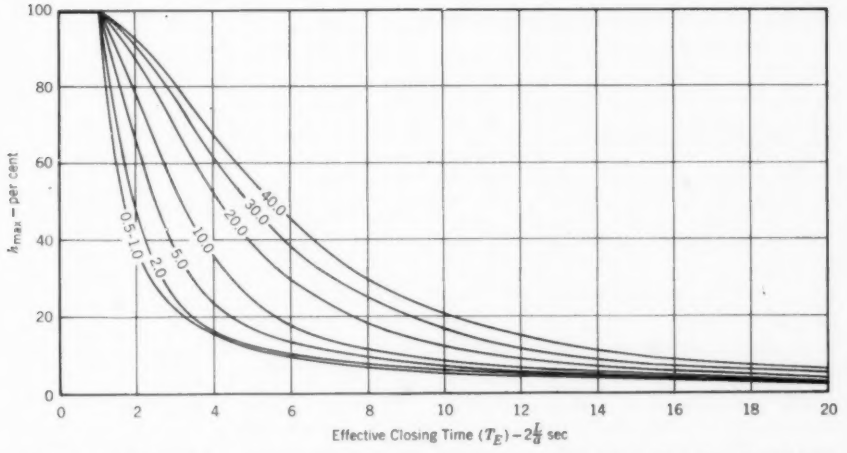


Fig. 8. Relationship of Pressure Rise to Effective Closure Time for Gravity Lines

Shown are the curves for gravity lines labeled according to their pipeline constants, K $\left(K = \frac{a\ V_o}{2g\ H_o}\right)$, *in which* a *is the velocity pressure wave in feet per second,* V_o *is the normal pipeline velocity in feet per second,* H_o *is the normal head in feet, and* g *is the acceleration due to gravity. The ordinate term,* h_{max}, *is equal to* $\frac{a}{g}$ *or* V.

The third column of Table 1 shows the calculated pressure rise for uniform cutoff of flow in five intervals of time. This pressure rise is expressed as a percentage of the instantaneous pressure rise.

The fourth column of Table 1 gives the valve factor, f, as found from test and as plotted in various illustrations in this article. The fifth column is the actual surge that would result if stem travel or plug rotation were made in five intervals for that particular system and valve characteristic.

The ratio of actual to assumed surge pressures is 2.4–5.8 times the assumed surges. It is evident from Table 1 that critical conditions will develop in each example shown unless allowance is made for the effective-time relationship.

Conclusion

It is suggested that more field test data of this sort be obtained by users, designers, and manufacturers to make available to the water industry true values of effective closure times under widely varying conditions.

It must be emphasized again that the value of the relationship of area to stroke is misleading; only the relationship of flow to stroke can be considered a sound basis for water hammer computations.

References

1. Goit, L. E. Water Hammer Studies on Long Pipelines. *Jour. AWWA*, 31:1893 (Nov. 1939).
2. Angus, R. W. Action of Valves in Pipes. *Jour. AWWA*, 30:1858 (Nov. 1938).
3. McPherson, M. B.; Strausser, H. S.; & Williams, J. C. Butterfly Valve Flow Characteristics. *Proc. ASCE, J. Hydraulics Div.*, Paper 1167 (Feb. 1957).
4. Kerr, S. L. Water Hammer Control. *Jour. AWWA*, 43:985 (Dec. 1951).
5. Kerr, S. L. Water Hammer—A Problem in Engineering Design. *Cons. Engr.*, 10:5:88 (May 1958).

Discussion

M. B. McPherson

Prof. of Hydraulic Eng., Univ. of Illinois, Urbana, Ill.

It is difficult to determine the head loss specific to a valve because it cannot easily be isolated from the head loss in contiguous piping, except under laboratory conditions. Even in the laboratory highly accurate measurements cannot be obtained at near-closed valve positions (small flows at peak head losses) or at near-open positions (small head losses and peak flows). The change in total head across a valve means the loss in addition to the pipe friction that would be present in the absence of the valve.

An extensive comparative study of butterfly valves[1] has shown that the least influence on flow characteristics arises from differences in closure angle (72–90 deg), except, of course, at near-closed positions. The blade shape has a relatively inconsequential effect on performance in all but the near-open positions, where the blade behaves as a crudely streamlined disturbance in the flow; the thickness of the blade influences the degree of disturbance and consequent head loss. The greatest influence on the performance of a given valve, however, is the type of piping used on either side.

Influence of Piping

Because of variations in structural design of butterfly valve blades, characteristics of both a typical and thin valve are shown in Fig. 9 in a uniform-

pipe installation—that is, an installation in which the piping on either side of the valve is the same diameter as the valve body. The thin blade cuts the flow at an extremely rapid initial rate. The curves for the two types of gate valves [2, 3] are very similar despite the difference in shape of opening. For Fig. 9 the total head across the valve is constant. This condition would be satisfied in an installation with a valve located between two constant-level reservoirs, provided that

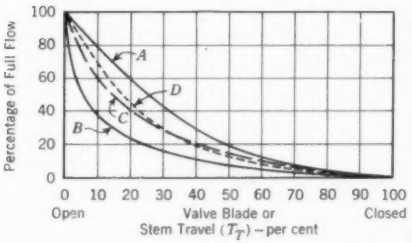


Fig. 9. Continuous-Pipe Characteristics at Constant Head Differential Across Valve (No Pipe Friction)

Curve A—*typical butterfly valve, hub thickness to valve diameter 0.2–0.3; Curve* B—*thin butterfly valve, hub thickness to valve diameter 0.1; Curve* C—*12-in. gate valve with rising stem, parallel seats, and crescent-shaped opening; Curve* D—*16-in. gate valve of ring follower type with rising stem and lens-shaped opening.* T_T *is not necessarily equal to percentage stroke.*

the valve loss greatly outweighed all other losses. Such an example may be of little importance from the standpoint of water hammer, but it offers a good comparison of the performance of different valve types; installations with pipe friction will be considered later.

The continuous-pipe curves for the 12-in. gate and typical butterfly valve of Fig. 9 have been graphed in Fig. 10, together with corresponding curves for a free-discharge installation.[1, 4] In a free-discharge installation, the valve is mounted at the terminus of a pipe having the same diameter as the valve body, and the downstream flange of the valve is in the open air. Free-discharge characteristics differ appreciably from those for a continuous pipe, and the effective time of closure is much longer. If a free-discharge valve releases water into a body of still water rather than into the atmosphere,[1] its

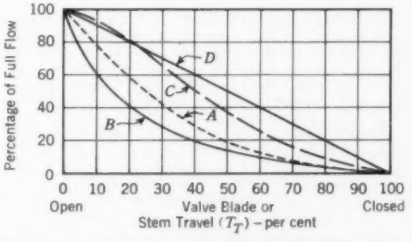


Fig. 10. Comparison of Continuous-Pipe and Free-Discharge Installation for Constant Head Differential Across Valve

Curves A *and* B *(from Fig. 9) are for continuous-pipe installations of a typical butterfly valve and a 12-in. gate valve, respectively; Curves* C *and* D *are for free discharge to the atmosphere, a typical butterfly valve and 8–12-in. gate valve, respectively. Percentage blade or stem travel is not necessarily equal to percentage stroke.*

characteristics are between those of the examples shown but closer to the free-discharge curve. If a valve is connected on either side, by means of reducers, to pipe that is larger than the valve, the effective closure time, with little or no pipe friction, would be greater (the curve initially less steep) than in a continuous-pipe installation; with substantial pipe friction, on the other hand, the effective closure time would be shorter.

The curve for a typical butterfly valve (Fig. 9) is reproduced in Fig. 11. Also shown is the characteristic of the same valve for closure from a position corresponding to 20 per cent of blade travel. The effective closure time is thereby reduced from approximately 50 per cent of the blade travel time to approximately 40 per cent, if the same rate of closure is assumed in both instances. Figure 11 is offered as a caution against possible comparisons of dissimilar initial operating conditions. It should be noted that the

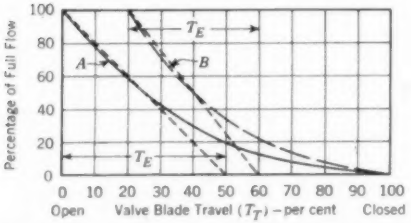


Fig. 11. Comparison of Initial Closure Positions for a Typical Butterfly Valve in a Continuous Pipe at Constant Head Differential

Curve A *(from Fig. 9) represents closure from the full open position; Curve* B *represents closure from the 20 per cent closed position.* T_T *is not necessarily equal to percentage stroke.*

phrase, "per cent of valve blade (or stem) travel," has been used in all four figures. The terminology is necessary, as it would be entirely misleading to attempt a generalization of linkage or actuator stroke in terms of blade or stem travel.

Pipe Friction

The effect of pipe friction in a uniform pipe installation is demonstrated in Fig. 12. The curve for a length-diameter ratio (L/D) of approximately zero is the same as Curve *A* in Fig. 9. The pipe friction head loss could be split up into any reasonable proportion on either side of the valve. These curves are applicable only to installations in which the terminal total heads are constant—that is, between two constant-level reservoirs. In such an installation, the difference in total head across the valve necessarily increases as pipe friction losses decrease. It may be seen that when the comparative pipe friction head loss becomes large relative to the valve loss—that

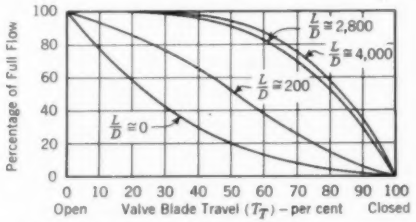


Fig. 12. Comparative Effect of Pipe Friction for a Typical Butterfly Valve in a Continuous Pipe

The curve for an L/D *ratio of approximately zero is Curve* A *from Fig. 9. Percentage blade or stem travel is not necessarily equal to percentage stroke.*

is, with a larger L/D ratio—the valve is relatively ineffective in controlling the flow until a near-closed position is approached. It should be noted that the effective closure time is noticeably diminished when pipe friction constitutes a larger share of the total head loss. Paradoxically, a thin butterfly valve would have a greater effective closure time than a thick-bodied valve in a long pipeline, but a lesser effective closure time in a short pipeline (Fig. 9). For a valve controlling flow during high demand into a distribution system without storage, the dropoff of service pressures resulting from closure of the

control valve would contribute to a further decrease in effective closure.

Significance of Estimates

The illustrations in this article represent specific installations under rather severe limitations. Although it is also possible to estimate the effective closure time for other types of installations, further generalization might be misleading. Even applications of the limited examples cited contain some degree of inexactitude stemming from the variability of valve characteristics and the inaccuracies inherent in estimations of pipe friction factors. Variations between operating mechanisms, valve body and seat designs, and installation design suggest that field measurements would be more reliable for local application.

It must be noted that the valve tests upon which the curves are based were performed under steady-flow conditions. It is not now possible to appraise the rate of closure or installation limitations for which the given characteristics would no longer apply for unsteady flow. Further, the reliability of any flow-cutting curve is dependent largely upon the accuracy of the flow coefficient for the fully open position, which, because of the very small head loss involved, is usually the least accurate.

Graphs that plot percentage of flow against percentage of valve blade travel are closed elliptical curves. It is therefore possible to write an equation describing any given curve and use it in complex water hammer analyses or incorporate it in an automatic-control program.

Conclusion

The purpose of this discussion has been to illustrate variations in the flow-cutting characteristics of valves caused by various specific factors. It is hoped that these comments have suggested reasons why general information is not available for application to a wider range of specific installations and why an attempt to oversimplify a valved system is poor practice.

References

1. McPherson, M. B.; Strausser, H. S.; & Williams, J. C., Jr. Butterfly Valve Flow Characteristics. *Proc. ASCE, J. Hydraulics Div.*, 83: Paper No. 1167 (Feb. 1957); discussions in Vol. 93 (Aug. 1957) and Vol. 84 (Feb. 1958).
2. Corps, C. I. & Ruble, R. O. Experiments on Loss of Head in Valves and Pipes of ½–12 in. Diameter. *Univ. Wis. Eng. Expt. Station Bul.*, **9**:1 (1922).
3. Hooper, L. J. Tests of 4-, 8-, and 16-in. Series 600 Rising-Stem Valves for the W-K-M Division of ACE Industries, Houston, Tex. Alden Hydraulic Laboratory, Worcester Polytechnic Institute, Worcester, Mass. (Sep. 1949).
4. Study of Gate Valves and Globe Valves as Flow Regulators for Irrigation Distribution Systems Under Heads up to About 125 ft of Water. Hydraulic Lab. Report No. Hyd-337, US Bureau of Reclamation, Denver, Colo. (Jan. 13, 1956).

Water Main Installation Across the Meramec River

E. Oliver Norman

A paper presented on Sep. 29, 1959, at the Missouri Section Meeting, Kansas City, Mo., by E. Oliver Norman, Staff Engr., St. Louis County Water Co., University City, Mo.

AS a result of industrial development and customer potential, the St. Louis County Water Co., in 1956, had to get a major transmission main across the Meramec River to serve the area west and south of the river, which had previously been the boundary of the company's service area.

The Meramec is a river of extremes, with rapid fluctuation between a low-stage flow of 127 mgd, to its all-time flood crest, when the river is about 35 ft higher, with a flow of 113 bgd. Overnight rises of 5–17 ft are not uncommon. This rapid fluctuation was of primary concern during the planning and installation of the crossing.

Crossing Site

Surveys of potential crossing sites indicated that, generally, the north bank of the river consisted of sand and gravel, changing to solid limestone at about midstream and sloping more or less uniformly up this rock bottom to the water's edge of the south bank. The south bank consisted primarily of water-deposited clay and sand with some loose boulders. Rapid currents were present in midstream.

The final choice of crossing site was dictated by the availability of easement and right of way and, to some extent, by the location of existing and potential customers. The final site was not the optimum crossing point from the standpoint of pipeline economy and river bottom topography, but it appeared to be the best available. Formal approval of the crossing was required from the US Army Corps of Engineers, because the Meramec is considered navigable at the crossing site. The terms of the permit dictated the conditions under which the crossing could be made and, to a large extent, governed the design details and equipment necessary for the project.

Installation

It was decided to install two 12-in. steel lines laid independently about 35 ft apart (the maximum spacing within available right of way) through the actual crossing. These lines were individually valved on each side of the river at points that would be accessible even when the water was extremely high. All joints below normal water level were welded, which involved approximately 300 ft of line for each crossing. Couplings * were used on the remaining 450 ft of each of the lines after they were welded into 80–100-ft sections aboveground.

To facilitate fabrication of the necessary 300 ft of 12-in. double random

* Made by Dresser Industries, Bradford, Pa.

pipe into a continuous length, cross-tie cribs were constructed on a continuous grade, and the pipe sections were laid up in proper alignment before welding was started. This enabled the welder to work in a normal position at all times. One helper was able to roll and position this pipe during the complete welding job.

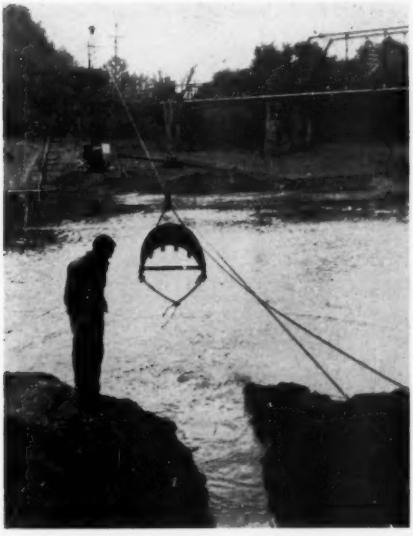


Fig. 1. Casting the Open Crescent Bucket to Opposite Bank

The carrier cable is strung from the top of the crane, shown in the background, to an anchor block on the opposite bank.

Dredging. A ¾-yd crane, with a 50-ft boom, was set up for a stationary drag-line, with a carrier cable from the top of the boom to an anchor block on the opposite bank. An open-bottom crescent-shaped bucket * rode a trolley on this cable and was cast by tightening the carrier cable and releasing the drag-line drum (Fig. 1). The return or digging cycle was operated by slacking the carrier cable and retrieving the bucket via the drag-line cable. The weight and shape of the special bucket caused it to drag along the bottom, pick up a load of gravel, and then act as a plow, until it was pulled up onto the bank immediately in front of the crane (Fig. 2). The bucket was unloaded by tightening the carrier cable and lifting it up into position for the next cast. Excavated material was disposed of by stockpiling with a front-end loader. Initially, a tracked rig was used; a 4-wheel drive unit with rubber tires was later found to be more advantageous.

With this method, a trench was dredged from bank to bank, extending on grade to a point above water level. The grade and condition of the underwater trench were then checked by sounding and by actual inspection by a diver. Generally, the trench was found to be straight, with uniformly sloped and very stable side walls. Some difficulty was experienced with buried logs on the beach side of the crossing. These were removed by blasting, the charges being set by the diver.

Pipe bedding. During fabrication, end caps had been welded to the ends of the crossing unit. These were equipped with tapped holes for pressure testing. The lead cap was equipped with a heavy eye. A cable was attached to this eye, run across the river, through a sheave attached to the anchor block, and run back across the river to the drag-line drum of the digging crane. The timber cradles used for fabricating the pipeline were greased, and the 300 ft of 12-in. pipe was pulled into place. Prior to this installation, a measured quantity of

* Manufactured by Sauerman Bros., Bellwood, Ill.

water was added to the pipe to make sure that it would not be buoyant. The bedding of the pipe was checked by sounding and by a diver. Some final adjustment was necessary, and lowering was accomplished by using the original digging setup and excavating immediately adjacent to the pipe.

With the pipe in place, it was necessary to provide anchors to hold it in position permanently. Initially, 5-cu yd concrete deadweight pads were poured around the pipe, filling the ditch at approximately the water's edge on each side. In addition, it was decided to set steel anchors into the rock, out from the south bank, and to build up and cover the pipe upstream and downstream with hand-placed one-man stone to provide a false bottom in that area of the river bed.

It should be mentioned that the pipe was installed without an exterior coating. It was decided, after careful study, that the installation methods required by other aspects of the work made it impossible to install a coated pipe without seriously damaging the coating. In addition, sections of the crossings could be subject to abrasive action by sand and gravel carried by the current. With these conditions in mind, heavy-wall ($\frac{3}{8}$-in.) pipe was purchased, allowing a large factor of safety for the working pressures encountered (150–155 psi).

Fig. 2. Retrieving the Open Crescent Bucket

When the bucket is being retrieved, its weight and shape cause it to drag along the bottom of the river and take on a load of gravel. The photograph shows the bucket being pulled up to the crane.

Work raft. To facilitate this work, a special raft, capable of carrying about

a ton of rock, was constructed with a hole in the center of the platform. By using ropes to opposite sides of the river, the raft was positioned over the spot chosen. Telescoping legs were then set on the river bottom and locked in place, furnishing a stable work platform to drill from (Fig. 3). A standard rotary drill, with special long steels, was used to drill into rock as much as 8 ft under water. As the drill steel was withdrawn from the completed hole, a diver inserted a J hook made from 1-in. reinforcing rod, with the hook over the pipe. Then he inserted a grouting tube that extended above the water surface. The grouting tube was filled with cement grout and rapped sharply with a hammer to work the grout down.

After the anchors were set, the raft was used to ferry one-man stone into position, using the same two-rope method as before. Final placement of the rock was done by a diver. Riprap was also laid on the banks above the waterline after backfilling. That portion of the pipe laid in the gravel trench was not backfilled mechanically, but was left open with the expectation that

Fig. 3. Construction of Work Raft

Stabilizing legs were provided with 9-in. square plates for firm support on the river bottom. The plates were locked in place by screw clamps (right foreground). In the background, the open crescent bucket is being retrieved.

subsequent high water would fill this slot naturally. During the following spring (1959), inspection by a diver showed that this filling-in was progressing but was not complete, because very little flooding had occurred during the intervening time.

Work period. As the work on these crossings progressed, it was found that, generally, 3–5 days of preparation, fabricating pipe, rigging cables, adjusting skids, and clearing bank slopes were required before work on the actual crossing could be started. Excavation of the actual crossing and installation of each of the pipes took 12–14 hr and was completed as one continuous operation to minimize the possibility of cave-in, river rise, or other unforeseen factors. No such difficulties were experienced. An additional 12–15 working days were required to complete the remainder of the piping, set rock anchors, place riprap, and clean up the site for the two crossings.

Pressure tests. After the individual crossing sections were fabricated, and before they were pulled into place, they were pressure tested with water at 150–155 psi for a 1-hr period. This test was repeated after the sections had been pulled into place. A third pressure test was conducted on the completed lines immediately prior to placing them into service. During these tests, all air was carefully bled out during filling, and the line was brought up to full pressure and then isolated by valving. Pressure gages showed no perceptible drop for a 1-hr period. In the final test of the completed lines, they were supplied with water through a meter sensitive to ¼-gpm flows. After the lines were full, this meter was watched closely for several hours before isolating the lines for the pressure gage test. There was no measurable leakage during any of these tests on either line.

Costs

The complete project used about 1,490 ft of 12-in. steel pipe, 620 ft of which consisted of the two river-crossing lines. The remainder of the pipe used was required to connect these lines to existing facilities on each side of the river, above normal high water. The total cost of the project was approximately $28,000. The total cost per foot of pipe was $18.80, made up of the following unit costs:

Material (pipe, fittings, and concrete), $7.10

Labor (preliminary and actual installation), $5.50

Engineering (preliminary investigation, design, and installation), $1.80

Mechanical equipment (crane backfiller, and trucking), $0.90

Insurance, social security, and overhead, $3.50.

Other methods might have been employed for the various phases of this operation. But those used have given completely satisfactory results at a reasonable cost.

Importance of Thrust Blocks for Pipe Installations

George G. Schmid and Elmer E. Bauhahn

A paper presented on Apr. 2, 1959, at the Michigan Section Regional Meeting, Mt. Clemens, Mich., by George G. Schmid, City Engr., and Elmer E. Bauhahn, Water Dept. Engr., both of Grand Rapids, Mich.

OVER a period of years, new materials and methods have been developed and added to those traditionally used in the water supply field. Among the materials now used for pipes are cast iron, steel, concrete, wrought iron, asbestos-cement, and plastics. A wide variety of joints are available, such as bell and spigot, flanged, ball and socket, sleeve-type, screw, mechanical, and compression-type joints, each with its own particular merit. The sealing materials used include melted lead, lead wool, sulfur base compound, portland cement, and rubber or rubber-type composition gaskets. From these materials and joints, a suitable combination probably can be selected for almost any field condition. Necessary blocking, however, is required with joints that do not provide protection against the movement of fittings and plugs.

The Cast-Iron Pipe Research Association states [1]:

> Supports should be constructed behind all bends, tees, caps, and plugs. They should be designed to carry the load that will be imposed upon them with the pipe working under its maximum head, and with a reasonable allowance for water hammer.

The AWWA standard for cast-iron main installation [2] states that:

> All plugs, caps, tees, and bends deflecting 22½ deg or more on mains 8 in. in diameter or larger shall be provided with a reaction backing, or movement shall be prevented by attaching suitable metal rods or clamps. . . .

The Johns-Manville installation manual [3] offers a good engineering approach to the same problem.

Pipe Joints

Mechanical-joint cast-iron pipe, used satisfactorily for several years, has become the standard of many water departments. The joint has a rubber or composition gasket, compressed and held in place by a bolted follower ring. Experience has shown that this type of compression joint, which is based on the stuffing-box principle, is tight and leakproof and, in addition, is quite flexible. Many water utility men prefer it to the poured-lead joint, which is more rigid. Other types of rubber joints, such as the roll-on joint, have been utilized in many satisfactory installations. The roll-on joint uses a round rubber ring gasket placed over the spigot end of the pipe, forced over a restriction ring in the bell and compressed in place, covered by a strand of square braided jute, and, finally, covered with bituminous joint compound.

More recently, a compression joint has been introduced for use with cast-

TABLE 1

Reaction Loads at Pipe Bends and Plugs Under Various Pressures*

Pipe ID *in.*	Reaction Load—*lb*							
	Plug	90-deg Bend	60-deg Bend	45-deg Bend	30-deg Bend	22½-deg Bend	11¼-deg Bend	5½-deg Bend
100-psig Internal Pressure								
4	1,260	1,780	1,260	960	650	490	25	120
6	2,830	4,000	2,830	2,160	1,460	1,100	550	280
8	5,030	7,100	5,030	3,850	2,610	1,960	980	490
12	11,300	16,000	11,300	8,630	5,850	4,400	2,210	1,110
16	20,110	28,420	20,110	15,370	10,420	7,840	3,940	1,970
20	31,420	44,450	31,420	24,000	16,300	12,270	6,160	3,080
24	45,240	64,000	45,240	34,600	23,450	17,600	8,860	4,440
150-psig Internal Pressure								
4	1,890	2,670	1,890	1,440	975	735	375	180
6	4,250	6,000	4,250	3,240	2,190	1,650	825	420
8	7,545	10,650	7,545	5,775	3,915	2,940	1,470	735
12	16,950	24,000	16,950	12,945	8,775	6,600	3,315	1,665
16	30,165	42,630	30,165	23,055	15,630	11,760	5,910	2,955
20	47,130	66,675	47,130	36,000	24,450	18,450	9,240	4,620
24	67,860	96,000	67,860	51,900	35,175	26,400	13,290	6,660
200-psig Internal Pressure								
4	2,520	3,560	2,520	1,920	1,300	980	500	240
6	5,660	8,000	5,660	4,320	2,920	2,200	1,100	560
8	10,060	14,200	10,060	7,700	5,220	3,920	1,960	980
12	22,600	32,000	22,600	17,260	11,600	8,800	4,420	2,220
16	40,220	56,840	40,220	30,740	20,840	15,680	7,880	3,940
20	61,840	83,900	61,840	48,000	32,600	24,540	12,320	6,160
24	90,480	128,000	90,480	69,200	41,900	35,200	16,720	8,880
250-psig Internal Pressure								
4	3,050	4,450	3,150	2,400	1,625	1,225	625	300
6	7,075	10,000	7,075	5,400	3,650	2,750	1,375	700
8	12,575	17,750	12,575	9,725	6,525	4,900	2,450	1,225
12	28,250	40,000	28,250	21,575	14,625	11,000	5,525	2,775
16	50,275	71,050	50,275	38,425	26,050	19,600	9,850	4,925
20	78,550	111,125	78,550	60,000	40,750	30,675	15,400	7,700
24	113,100	160,000	113,100	86,500	58,625	44,000	22,150	11,060

* Reaction loads for this table have been calculated using the outside diameter of pipe and the formula:

$$R = 2\,a\,p \sin \tfrac{1}{2} \text{ (angle of pipe bend)}$$

in which R represents the reaction load; a, the area of the pipe at the joint considered as a piston; and p, the fluid pressure in pounds per square inch.

TABLE 1—*Reaction Loads (contd.)*

Pipe ID *in.*	Reaction Load—*lb*							
	Plug	90-deg Bend	60-deg Bend	45-deg Bend	30-deg Bend	22½-deg Bend	11¼-deg Bend	5⅝-deg Bend
	300-psig Internal Pressure							
4	3,780	5,340	3,780	2,880	1,850	1,470	750	360
6	8,490	12,000	8,490	6,480	4,380	3,300	1,650	840
8	15,090	21,300	15,090	11,550	7,830	5,800	2,940	1,470
12	33,900	48,000	33,900	25,890	17,550	13,200	6,630	3,330
16	60,330	85,260	60,330	46,110	31,200	23,520	11,820	5,910
20	94,260	133,350	94,260	72,000	48,900	36,810	18,480	9,240
24	135,720	192,000	135,720	103,800	70,350	52,800	25,680	13,320

iron water pipe. It has a rubber gasket shaped to fit into a recess in the bell. The spigot end of the pipe is forced or pushed into place in the bell, thus holding the gasket in place. This type of joint is said to provide maximum sealability under pressure and secondary sealing in case of deflection or excessive settlement. Although this joint has not been in use as long as other types of rubber or composition joints, it has demonstrated satisfactory protection against leakage and can be quickly and easily installed, even under adverse conditions. The ease and speed with which mechanical and compression joints can be made do not, however, warrant any lessening of effort and attention with regard to the proper laying of the main and fittings, and the providing of proper and necessary blocking and anchorage.

Installation of Mains

In general, in installation of water mains, unnecessary excavation should be avoided. After the soil has been loosened, it is difficult, if not impossible, to get it back into the same compact form as before excavation. Careful tamping and consolidation, although effective and absolutely necessary, are not the only things needed for restoring stability to the excavated area. Every effort should be made to insure that the water main is properly bedded, that it has firm bearing, and, when required, that it is anchored and blocked at all free ends and bends so as to resist the thrust of the water in the mains. It is worth reemphasizing that although mechanical and compression joints have the flexibility to resist minor settlement without leakage, this feature must not be considered a substitute for proper installation practice.

Leaks

Even if the water main passes the initial leakage test, it is possible that, later on, the action of traffic, frost, or impact will cause leaky joints. A leak may be very small and remain undected until water appears on the surface. Until that time the leak could be undermining a pavement or slowly washing away the firm foundation under the pipe. Care taken with the initial installation and proper blocking and anchorage will reduce considerably the need for repairs. In new installations, or when necessary in repair

work, supports should be provided at tees, bends, reducers, crosses, plugs, dead ends, valves, and hydrants. Fittings must be supported independently of the pipe, because only a small connecting force is available.

Supports

Supports are frequently called anchorage, thrust blocks, or blocking. Their size depends on the type or size of fitting or pipe, the pressure in the mains, and the kind of soil or laying condition, and should be increased with the size of the water main and with the increase in pressure in the mains. In unstable soil or trenches, it is advisable that the weight of the anchorage or blocking be sufficient to compensate for the thrust in the main. And in many instances, special combinations of blocking and supports, and even tie rods, are used to retain the water main or fitting. A soft and yielding soil is usually entirely removed and suitable soil or backfill substituted.

This discussion, which is confined to general and average conditions, should not be considered a substitute for the judgment of an experienced engineer or utility manager who is familiar with the specific installation and the conditions surrounding it. In all instances, whenever possible, the selection of a particular combination of anchorage and blocking should be made after a careful study, if the most satisfactory and economical structure and support are to be provided.

Water Hammer

In addition to the thrust caused by static water pressures is that caused by water hammer or surge. Fortunately, manufacturers have added a safety factor in the design of pipe and fittings, so that 70–120 psig above the design pressure can be safely contained. Water hammer and surges can be alleviated through the use of pressure control devices, surge tanks, cushioned check valves, overflow pipes, and elevated tanks, all of which do a good job. But even with the most complete system and under ideal conditions, sections of the main can be subjected to suddenly rising pressures. A hydrant or valve closed too quickly, a check

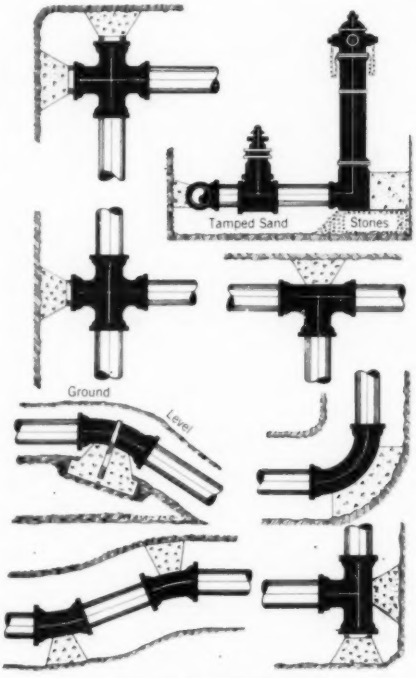


Fig. 1. Thrust Blocks for Typical Pipe Fittings

The location of the thrust block depends on the direction of the thrust in the pipe and on the type of fitting. Thrust blocks are placed between the fitting and the undisturbed trench wall.

valve in the line suddenly closing, or the power supply of a centrifugal pump being momentarily shut off can cause a disturbance. The column of water has built up momentum and wants to keep going, and a pressure at least equal to that normally in the mains may be built up if there is no stoppage. If there is a stoppage along the line, the pressure head can be more than twice the normal pressure. The velocity head goes into shock pressure and can be felt for a considerable run of pipe. The condition is aggravated as the flow is reversed.

Although water is generally thought of as being incompressible, and pressures believed to be transmitted undiminished through the mains, water is actually slightly compressible, and pipe can be expanded. If this were not so, it is likely that there would be more blown-out joints and ruptured pipes. When some disturbance causes water hammer, thumping and banging in the mains may occur. Long as well as short stretches of main are affected, and conditions of maximum pressure can be found in each. There is as much danger of rupture in mains operating at high pressures as in those operating at low pressures.

Safe Bearing Load and Thrust

Anchorage or blocking should be designed to carry the load, with a reasonable allowance for water hammer, when the pipe is subjected to its maximum head. If the water main is subjected to a maximum pressure of 75 psi, and an allowance of 75 psi is made for water hammer, then the total test pressure on the main should be 150 psi. Table 1 gives the reaction, or thrust, for different types of ends and bends under various pressures. The table shows that for the larger pipe, at the higher pressures, the thrust can be of considerable magnitude. The size of a thrust block or anchorage to retain the pipe or fitting depends on the safe bearing capacity of the soil. Table 2 shows the safe bearing loads of several types of soil and a factor to be used to modify the required thrust block areas. Table 3 shows minimum thrust block areas for installation conditions in soil with a safe bearing load of 2,000 psi, and for pipes with inside diameters as large as 12 in. The location of the thrust block depends on the direction of the thrust in the mains and the type of fitting. Figure 1 shows thrust blocks for typical fittings. Practically all thrust in water mains is horizontal or vertical. The weight of the earth filling, properly tamped, usually retains the vertical thrust. If there is any doubt, the error should be on the side of safety, and thrust blocks should be provided for vertical thrusts. Thrust blocks are usually made of concrete, placed between the fitting and the undisturbed trench wall, which is trimmed

TABLE 2

*Safe Bearing Loads of Soils and Multiplication Factors for Modification of Thrust Block Areas**

Soil	Safe Bearing Load *psf*	Factor
Muck, peat	0	†
Soft clay	500	4.00
Sand	1,000	2.00
Sand & gravel	1,500	1.33
Sand & gravel cemented with clay	2,000	1.00
Shale	5,000	0.40

* Some thrust block areas are shown in Table 3.
† Thrust retained by weight of anchorage, ties, rods, piles, or removal of muck or peat and replacement with materials of suitable stability to provide firm bearing.

to an even face with clearance so that joints can be worked on later. For the smaller water mains, forms for the concrete need not be elaborate, just sufficient to keep the concrete in shape. For water mains 12 in. and larger, forms should be used, and in many instances the thrust may be provided for by encasing the water main in concrete. It is possible, with proper tamp-

TABLE 3

Minimum Thrust Block Areas Required at Pipe Bends and Plugs Under Various Internal Pressures in Granular Soils With a Safe Bearing Load of 2,000 psf*

Pipe ID *in.*	Thrust Block Area—*sq ft*							
	Plug	90-deg Bend	60-deg Bend	45-deg Bend	30-deg Bend	22½-deg Bend	11¼-deg Bend	5½-deg Bend
100-psig Internal Pressure								
4	1	1	1	1				
6	2	2	2	1	1	1		
8	3	3	3	2	1	1		
12	6	8	6	4	3	2	1	1
150-psig Internal Pressure								
4	1	1	1	1	½			
6	2	3	2	2	1	1		
8	4	5	4	3	2	1	1	
12	8	12	8	6	4	3	2	1
200-psig Internal Pressure								
4	1	2	1	1	1			
6	3	4	3	2	2	1	1	
8	5	7	5	4	3	2	1	
12	11	16	11	9	6	4	2	1
250-psig Internal Pressure								
4	2	2	2	1	1	1		
6	4	5	4	3	2	1	1	
8	6	9	6	5	3	3	1	1
12	14	20	14	11	7	6	3	1
300-psig Internal Pressure								
4	2	3	2	1	1	1		
6	4	6	4	3	2	2	1	
8	8	11	8	6	4	3	2	1
12	17	24	17	13	9	7	3	1

* The friction of the anchorage against the soil beneath it has not been considered in the above tabulation. Under some conditions, it may be possible to reduce the thrust block area in proportion to the weight of the anchorage bearing against the soil.

ing and consolidation, that the progresssive settlement of the earth filling around the water main and fitting will provide all the stability that is required, particularly in the smaller pipe and at slight bends. Buried pipe has been kept in place without thrust blocks or anchorage by the action of a well compacted earth covering. But fittings that stayed in place for several years have been known to blow out and cause considerable property damage because the support failed.

Conclusion

Because there is a likelihood of shock pressure, surges, and soil movement from freezing and thawing cycles, provision should be made for absorbing the thrusts at various pipe fittings. If there is reason to doubt the stability of an assembly, sufficient thrust blocking should be provided.

References

1. *Handbook of Cast Iron Pipe.* Cast Iron Pipe Assn., Chicago (2nd ed., 1952). p. 51.
2. Tentative AWWA Standard for Installation of Cast-Iron Water Mains—AWWA C600. Am. Wtr. Wks. Assn., New York (1954).
3. *Piping Handbook.* Sabin Crocker, ed. McGraw-Hill Book Co., New York (4th ed., 1954). p. 1055.

AWWA Meter Manual Available

Water Meters—Selection, Installation, Testing, and Maintenance, which was published as a series in the June–September 1959 issues of the JOURNAL, is now available as a separate manual (AWWA M6), indexed and attractively bound in stiff-paper covers. Prepared by the AWWA Meter Committee, this informative 88-page book is priced at $1.25 a copy.

Design and Installation of Intakes for Canadian Supplies

John W. Argo

A paper presented on May 6, 1959, at the Canadian Section Meeting, Montreal, Que., by John W. Argo, Vice-Pres., Gore & Storrie, Cons. Engrs., Toronto, Ont.

THE design and construction of intakes are subjects that should be of interest to operators of all water systems utilizing a surface source, whether it be a river or a lake. The main problems of intake design are rather general and are probably applicable to most systems, although the construction equipment and methods locally available must be considered. Further, intakes for Canadian conditions present some problems, such as ice, which are not encountered in intakes in milder climates.

The term "intake" refers to the portion of the water system that conveys water from the source of supply to the treatment plant or pumping station. It includes the inlet structure and the conduit required to convey the water from the inlet to the plant.

Selection of Source

As intakes may be located on either rivers or lakes, their design and the method of their construction vary with the location and the conditions under which they will be operated. Thus, the first and most important consideration in the planning of a new intake is its location, which will usually determine the quality of the water delivered to the treatment plant or to the distribution system. Because an intake cannot be easily altered, special care must be taken in determining its location. In developing a new water supply system, there is usually some latitude in choice of location. In many municipalities in Canada there is a suitable source within a reasonable distance, either a river or lake, but it has sometimes been necessary to draw water from a source many miles away.

After a water source has been selected, the intake should be so placed, with consideration for economy of construction, so as to draw off the most suitable water available and so as to be as free as possible from difficulties of operation. When a new intake is required to serve an existing water system, its position is frequently dictated by the location of the existing plant. Even then, however, there is some latitude in the exact location of the inlet structure, and its final position should be the subject of careful study. It sometimes happens that changes in local conditions cause such deterioration in the quality of the water supply that consideration should be given to relocation of the treatment facilities as well. The development of new harbors and industries along the shores of many lakes may increase pollution of the waters drawn into intakes constructed a number of years ago.

The quality of the raw water should be the first consideration in choosing

the location of an inlet structure. Because the quality of raw water determines the degree of treatment required, the location of the intake may materially affect the cost of producing water.

To be distributed without treatment or with chlorination only, raw water must be of a high quality. This means that the source must be free from pollution or adequately purified by natural agents.

If the raw water is to be treated in a plant, its quality may materially affect the cost of treatment. It is sometimes considered that a treatment plant is overloaded if the average coliform count in the raw water is higher than 500 in 100 ml or if, in 0.1-ml samples, coliform organisms are present 50 per cent of the time. Such a standard should be a general guide to good practice, but local conditions may require use of more highly polluted water. With sand filtration and chlorination combined, a raw water coliform count of up to 5,000 per 100 ml may be acceptable, provided the equipment and operation of the treatment plant are of a high quality.

The source selected should supply satisfactory answers to a number of important questions for present and future requirements of the community: Is the source ample? Is it free from excessive pollution from sewage or industrial wastes which might be drawn into the intake? Is it subject to periodic flooding or turbidity from storms or surface runoff? Is the bottom of the source rocky or covered with silt which may be stirred up at time of high flows or storm? Is the water free from excessive color, hardness, algae, or other objectionable characteristics that cannot be easily removed? Can water from the source be treated and delivered to the community economically?

Location at Source

After the most suitable source of supply has been selected, the location of the intake at the source must be very carefully considered.

If the intake is to be constructed in a lake, a study should be made of local sources of pollution and currents, for lake currents may carry pollution in cloudlike masses for many miles. In Lake Ontario, for example, the general flow of the lake is from west to east, but strong currents in the opposite direction are frequently noticed. The currents are affected by wind action but may continue for some time after the wind has shifted. Such currents have been responsible for the building up of Toronto Island and have caused trouble in maintaining the original intake pipes laid out from the island into Lake Ontario, and they make necessary continual vigilance in the operation of water and sewage treatments plants.

For river intakes, surveys of local pollution and currents should also be made. The intake should be located upstream of outlets from sewers or industrial-waste sources if at all possible, but even then eddy currents may sometimes carry such pollutants over the intake.

Careful surveys should always be made of the bed of the lake or river, especially near the inlet site. Such surveys should provide contours of the bottom and also samples of the material composing the bottom. The nature of the bed, whether of rock, sand, or silt, is an important consideration in the design of the inlet and conduit structures. In one Toronto intake, laid in a sand bottom about 1898, sections near shore were undermined by the

current and collapsed. They were replaced on wood pile bents and steel piling driven on both sides of the pipe. Recently, the author examined an intake in Lake Erie which had been laid in a sand bottom. The pipe had been undermined and damaged; sand had been drawn into the pipe, almost completely filling it, and the inlet structure was almost completely demolished. The whole pipe had to be scraped and reconditioned, and a new inlet structure was constructed that could withstand wave action on an insecure bed.

Capacity

Because an intake cannot be duplicated without considerable expense, it should have a capacity sufficient to provide for the predictable needs of the community for a long time.

The cost of installing an intake pipe does not increase in direct proportion to diameter, whereas the carrying capacity increases approximately as the square of the diameter. As the excavation for a pipe in a lake is usually much wider than is actually required and the laying cost is not much different, a large pipe can be installed at only slightly more cost. Thus a 30- or 36-in. intake pipe exceeds the cost of a 24-in. pipe by a little more than the increased cost of the pipe, itself.

The capacity of the pipe should be calculated when the water level of the source is lowest, and losses in the inlet, friction losses, and losses through the valve and screen at the suction well should all be considered. Careful hydraulic design can materially increase the available capacity of the intake structure.

Inlet Types

Many of the older inlets in rivers and lakes were simply elbows supported by timber cribs on the bottom with vertical riser pipes to draw water from a short distance above the bottom. Frequently a screen was placed over the inlet pipe, or a perforated metal extension of the inlet pipe was used. The author knows of one inlet which is equipped with an old boiler shell for a screen. The screen probably does not do much good, but it has not interfered with operation as yet. Such an inlet is rarely satisfactory, except for very small supplies. The turned-up pipe usually has a high entrance velocity and a tendency to draw ice, sticks, fish, and sand into the intake. Although screens are designed to strain out such trash, they eventually become clogged with dirt and reduce the rate of flow. Furthermore, corrosion or incrustation of the screen may cause blockage. A better place for the screen is in the pump well where it may be cleaned easily. A coarse bar screen may be installed at the inlet to keep out larger objects.

A preferred type of inlet structure for lake intakes is one in which an elbow is built into a concrete, timber, or stone crib set on the bottom. Above the elbow is a bell mouth of cast iron, steel or concrete. A plate of steel or concrete is placed horizontally above the bell mouth, forming a square or cylindrical inlet of large area and producing a low inlet velocity. The height of the opening should be small compared with the diameter. In this type of inlet the water is drawn horizontally into the inlet at a velocity about 6 ips. This effectively prevents formation of vertical currents and vortices and thus reduces the hazard of drawing ice, sticks, fish, and other debris into the intake. The hydraulic losses in such an inlet are much smaller than in a simple pipe inlet.

Inlet structures in rivers usually differ from those in lakes, because of

the more rapid currents in the rivers. The location and character of the river may be such that water can be drawn directly from the river into a gatehouse or pumping station. In such instances water may be drawn through ports in a wall, or through a pier projecting slightly out from the bank. Such arrangements are usually practicable only in special locations, such as on large, deep rivers or in dams. Usually in river sources, and almost invariably in lake sources, it is necessary to obtain water at reasonable distance out from shore to avoid shore pollution.

If an intake with a horizontal top plate were placed in a river, the river current would be parallel to the plate and destroy its effectiveness. Thus, in rivers with appreciable current, it is advisable to place the inlet horizontally with the axis at right angles to the current, so the current will flow past it. The inlet may be made in the form of an eccentric cone, the outer diameter of which should be such that the inlet velocity is low (preferably not more than 6 ips). The rate of contraction of the cone should be small in order to keep hydraulic losses to a minimum.

Intake Hazards

An intake should be designed to avoid as many as possible of the hazards to which such structures may be subjected.

In Canada and other northern areas one of the greatest hazards to water intakes is blocking by ice, which may occur 4–5 months of the year. Ice may be of several types: surface, anchor, frazil, or slush ice. Surface ice is that which forms on the surface of the water and usually does not cause physical trouble in the intake structures, but may cause other problems. When a lake or stream freezes over, oxidation from the surface is prevented and any pollution in the water may be carried below the ice into the intake. This problem can only be overcome by removal of the pollutants. In Edmonton, Alta., for instance, sewage treatment plant effluent is discharged into the Saskatchewan River, which freezes over in the winter when flow is a minimum. Much more sewage treatment is required in the winter to protect users of the river downstream from the city. Where the water supply is subject to such seasonal dangers, extra care is required in operation of treatment processes.

Anchor ice forms beneath the surface and on surfaces which radiate heat rapidly, such as valves and gratings. It is formed especially at night in clear, cold water when opaque surface ice has not formed. It is especially dangerous in clogging screens constructed on the inlets but may also cause difficulty by collecting on well screens.

Frazil, or needle, ice consists of submerged ice crystals, which may be anchor ice that has broken loose or may form as crystals about nuclei in the water. Each crystal acts as a nucleus for further crystals and the process continues until a slushy mass is formed. As ice is only slightly lighter than water, it is easily drawn into the intake by even relatively low water velocities and will frequently clog screens and even the whole intake structure.

Probably the easiest method of dislodging ice is by reversing the flow of water through the intake, which usually requires that a large quantity of water be delivered from the distribution system or storage. Severe clogging may make it necessary to melt or chip the ice. In some places screens are heated very slightly to prevent formation or adhesion of ice. Thus, because ice can cause so much difficulty

in operation, it is worthwhile to design the intake carefully to reduce such problems to a minimum.

Damage may also be caused to intakes by mechanical hazards, such as dragging anchors, logs, and heavy debris. In navigable waters the inlet structure should be constructed in water sufficiently deep to insure reasonable protection against damage from ships. Although it is virtually impossible to guarantee that a dragging anchor will never catch an inlet structure, the hazard is lessened if the location is marked with a buoy near the inlet. In some places, where shipping must pass nearby the inlet in narrow waters, the inlet can be protected by a cluster of timber piles driven into the bottom and projecting above water with navigation lights.

The pipe conduit joining the inlet to the suction well is also exposed to danger from anchors. It is best protected by being laid in a trench either wholly or partially buried below the lake or river bottom. If partially buried, an anchor is more likely to slide off the pipe than if it is laid above the bottom, especially if a smooth-walled pipe is used.

Mention has been made of the danger of undermining intakes laid on a soft bottom. If the pipe is undermined it is likely to settle, thus opening one or more joints or buckling. These dangers can be overcome by selecting an alternative site with a solid bottom, supporting the pipe on pile bents, or laying it at a greater depth where solid support may be found. If there is a strong current parallel to shore and it strikes a pipe laid on, or slightly above, the bottom, the pipe can be undermined very rapidly. Sometimes another current or wave action replaces the sand and re-covers the pipe, but not before damage results.

Intakes are usually designed with large enough capacity to allow for future expansion of the system. This may cause some temporary trouble. For example, an intake was constructed about 8 years ago in Lake Ontario. The water use at that time was 1.5 mgd, but the intake was constructed to have a capacity of 12 mgd, as it was in a rapidly growing community. Over the past 8 years the velocity in the intake has been so low that much of the turbidity in the water has settled out. The present flow rates of 6.0 mgd have dislodged most of the sediment, but, as the hydraulic coefficient of the intake is somewhat lower than expected, there may still be some silt deposited in the pipe. It may have to be dislodged by dragging a chain or scraper through the pipe.

Another difficulty experienced with intakes is air binding caused by laying the pipe with a high spot. An intake pipe should always be laid with a continuous slope between the inlet and the pump suction well, usually with the suction well higher than the inlet. This usually requires an expensive excavation at the shore end, and some intakes have therefore been laid with a high spot near the shore, the pipe sloping down to both ends. All raw water contains some air in solution, and it is released in an intake pipe when the latter is operated under slightly reduced pressure. If the intake pipe is laid with a continuous slope, air finds its way to the high end and escapes. If, however, the pipe has a high point, air accumulates and may seriously reduce the capacity of the intake. Special care should be taken to check the elevation of each section of pipe as it is laid to insure that it is placed on a continuous slope.

If a high point is unavoidable, provision should be made to withdraw

accumulated air. In the intake for the R. C. Harris Plant of Metropolitan Toronto, two pipes laid on the bottom of the lake lead to an underwater shaft which joins to a tunnel at a lower depth leading to the pumping station. The top of the shaft is a high point from which air can be conducted to the pumping station through a small copper pipe built along with the tunnel section. No difficulty has been experienced with this arrangement.

Conduit Pipe

The pipe connecting the inlet structure to the pump well may be of any of several types. Small intakes have frequently been built of cast-iron pipe and steel pipe has been common in larger intakes. Steel pipe may be of riveted or welded construction and the plate is frequently $\frac{3}{8}$ in. thick or thicker. Steel pipe is often lined with a coal-tar coating which may be spun on. The outside may be wrapped with an asphalt-impregnated wrapping for protection against corrosion. The weakness of this wrapping is that it must be stopped at the joints, which are somewhat susceptible to corrosion. This type of construction has been successfully used on many intakes for a long time, however. Steel pipe has the distinct advantage that it is light and strong and may be welded into long lengths with fewer underwater joints. In some intakes, an electric potential is applied to the steel pipe to protect against corrosion, but the effectiveness of this procedure has not been fully determined.

Joints in cast-iron or steel pipe intakes should be arranged for easy assembly under water, because a diver must work in poor light or semidarkness and is handicapped by difficulty of movement under water. Joints should also be designed to allow for possible settlement of the pipeline and to follow the bottom. With cast-iron or steel pipe, flanged joints with wooden gaskets have been used successfully, although the large number of bolts required causes difficulty in assembly. Couplings of the split-ring type are difficult to assemble under water, because they must be accurately aligned and spaced. Sleeve couplings with rubber gaskets are common in intakes, as they can be installed fairly easily and do not require many bolts. Such couplings may be galvanized to protect against corrosion. They are not strong enough to prevent the joint from pulling apart, so that two lugs are welded to the pipes on each side of the joint and tie bolts are installed. The latter also assist in inserting the pipes; if the length of the tie bolts is carefully set, it will insure that the joints are properly pulled home, for otherwise the nuts cannot be placed on both ends.

In recent years, precast concrete pipe has been used in many intakes with satisfactory results. The pipe is usually noncylindrical pressure pipe, frequently made up in 16-ft lengths. These may be welded together in the shop to make 32-ft lengths if the placing equipment is heavy enough to handle the longer pipe. Joints in this pipe may be bell-and-spigot type formed from cast-steel rings welded to the reinforcing steel in the shop. A rubber gasket is placed on the spigot and is compressed when the spigot is forced into the bell. The design of the bell and spigot is preferably such that the gasket is set in a groove. It is advisable to weld two lugs at each end of each pipe and to use two tie bolts to pull the joint home. The tie bolts are loosened somewhat after the complete pipe has been laid to provide flexibility. Intakes of this type have

been tested for leakage and found to be very nearly watertight. Concrete pipe has a higher hydraulic coefficient than can be expected with steel or cast-iron pipe after a few years use. On the other hand, concrete pipe is much heavier and thus requires heavier handling and placing equipment.

Large Intakes

An intake for larger supplies must be designed especially to suit the conditions. The R. C. Harris Plant of Metropolitan Toronto has a capacity of 240 mgd. The intake consists of a 10-ft tunnel driven though shale from a shaft at the pumping station to a point 3,300 ft out into the lake, where the water is approximately 33 ft deep, and terminating in a junction shaft rising up to the lake bottom. From this point one pipe 8 ft in diameter was laid on the lake bottom for 4,150 ft to a position where the depth is 53 ft. Provision was made for two additional pipes, one of which has recently been installed. Each intake branch has a butterfly valve which may be operated by air or water pressure applied from the surface to a pressure cylinder. The branch pipes were built on shore of steel pipe with concrete lining and a concrete envelope. The inlet crib on each pipe is 30 ft in diameter, built of steel plate, and filled with concrete. The inlet is a steel plate bell mouth, with a dished cover plate, forming a cylindrical opening 20 ft in diameter and 4 ft high. An intake of this size is unusual and the type of construction is not often applicable.

Another form of inlet for large supplies consists of a tower built from the bottom to a point above the highest water level. Ports with gates are arranged at different levels to allow water to be drawn from the most suitable depth at any given time. Such structures can be protected against shipping hazards and are better able to avoid turbidity and ice troubles.

Suction Wells

An intake usually discharges water to a suction well from which it is pumped to the treatment plant or directly into the distribution system. A valve is placed on the shore end of the intake pipe, frequently where it enters the suction well. The intake valve may be manually operated as it is closed only occasionally. However, hydraulic or electric operation allows rapid opening to flush out the intake pipe and the additional cost is sometimes warranted. The connection for backwashing to remove ice is made outside the intake valve by a valved pipe connected to a large tank, pump, or discharge main.

The suction well should be large enough to accommodate the suction pipes of all pumps which will be connected to it and should be deep enough to provide water over the suction pipes at the greatest pumping rate for which the intake is designed at times of minimum water level in the source of supply.

An overflow from the suction well may be required to relieve surges due to sudden stoppage of the pumps. If the intake is short and the velocity low, the surge may be accommodated by increased capacity in the upper part of the suction well, but for a long intake with high velocity the well usually is not deep enough and overflow relief is required. If surge is not provided for, serious flooding of the pumping station may result.

In some intakes the top of the well has been placed above high-water level to allow for the use of horizontal pumps; in others the well top has been lowered to provide reduced suction

lift. In the latter installations, vertical pumps, driven by motors placed on a higher floor, have been used. Care should always be taken to guard against flooding of the pumping station by surge or any other cause.

Screens

Screens consisting of corrosion-resistant wire mesh with openings $\frac{3}{8}$ in. square are usually placed in the suction well.

Screens may be mounted on removable steel frames installed in grooves in the walls of the chamber and designed to be lifted out manually for cleaning. The screen need not run the full height of the well but any space above should be blocked off by a steel plate or concrete wall. Manually operated screens are best installed in duplicate so the water is screened even when one screen is removed for cleaning.

Provision should be made for convenient hoisting of the screens and conveying to a suitable space for cleaning; a monorail hoist is particularly convenient. A suitable place should be provided where the screen can be washed by high-pressure hoses The washing area should be drained and the washings should be carried to waste; they should under no circumstances be allowed to re-enter the suction well.

When the raw water contains large quantities of algae or seaweed, screens may require frequent washing. Under these conditions a mechanically operated screen is warranted. Such a screen consists of corrosion-resistant screen sections mounted on endless chains running in guides the full depth of the well. The screens pass over a head frame where they are washed by water sprays and from which the screenings are flushed to a drain. Such a screen is more expensive, but it is warranted in larger supplies to reduce labor of cleaning. Power and maintenance costs of mechanical screens are low, as the screen need not be operated continuously. A differential switch operating on the level of water above and below the screen may be used either to start and stop the screen mechanism or to sound an alarm indicating clogging of the screen.

Construction and Design

When an intake is being designed, the engineer should consider carefully the methods and equipment required for construction. Large, heavy pipe can be handled only by heavy equipment, which may not always be readily available. In most communities on or near the larger rivers and lakes, large floating plants are usually available. In some places, however, such equipment is not available and the design should take this fact into consideration. An intake can often be successfully laid by a crane mounted on a towed scow equipped with spuds or some other means for holding its position. Such equipment is about the minimum required and is available in most places. Intakes have even been laid through the ice in winter.

Excavation of the shore section of the intake is usually fairly deep and is frequently carried out by land equipment. Some contractors elect to excavate the deep trench with floating equipment which digs its way in from the water. Sometimes a berm is built of excavated material and land equipment can be run out a considerable distance into the water.

The pipe should be laid in a trench until it is well beyond danger of damage from ice piled up along the shore, beyond which it may be laid on the bottom or in a trench. Sometimes irregularity of the bottom requires the

pipe to be partly on the bottom and partly in a trench.

The pipe should be laid carefully to grade on a smooth bed. It is usually supported at intervals of 10–12 ft on sand-and-cement bags, which are packed around both sides of the pipe. Pipe laid on the bottom may require anchorage to prevent lateral displacement by currents. On a rock bottom, pipe may be anchored by heavy bolts with split ends and wedges driven into drilled holes in the rock on both sides of the pipe and fastened across the top with soft galvanized wire twisted tight. As mentioned above, on a sand bottom, piles may be required.

Care must be taken in aligning the pipe so that the deflection at any joint does not exceed the safe deflection for the type of joint used, which may require extra depth in some spots.

After the trench or bottom is prepared, the pipe is brought from shore, supported on double slings and lowered into place. The placing must be accurate so the diver can make the joint without difficulty. In making joints with concrete pipe or pipe with sleeve connections, the pipe is entered into the joint and pulled home by tightening the draw bolts. These joints are easily and quickly made. Because flanged joints are much more difficult and slower to assemble, they are not so frequently used.

For a smaller intake the inlet structure may sometimes be built on shore and transported to its final position where it is placed on a carefully levelled bed. If the bottom is rock or hard material, the inlet crib may be placed directly at its design level. On a softer bed the inlet structure may be allowed to settle slightly to its own level before it is connected to the pipe. In any case the inlet structure should be as nearly level as possible.

Frequently a flexible joint is placed at the junction of the inlet to the intake pipe but this is not always necessary if the pipe is built with flexible joints.

Larger inlet structures may be built with timber or steel cribs. The crib is placed in position and filled with concrete or rocks, and the plate structure is then fastened above.

Excavated material is usually piled up beside the pipeline. After the pipe is placed, the trench, at least up to the center of the pipe, should be backfilled with good sand, free from rock. If necessary, sand should be brought in to insure complete and safe backfilling.

Costs

The cost of intake construction varies greatly, depending on availability of equipment and the location of the work. If the intake is to be constructed in an open section of a large lake and at some distance from a suitable harbor, the equipment may have to travel a long distance to and from the work each day. If the intake is located in a harbor or other sheltered waters, lost time will be at a minimum and the cost will be lower. The author recalls one intake laid with a scow which could be run up on shore whenever the lake became rough. The procedure was quite economical, although unusual.

It has been found that the cost of constructing intakes of moderate size depends largely on the location and length, whereas, within limits, the size affects only the cost of materials. Intakes laid in Lake Ontario in the vicinity of Toronto are frequently 2,500–3,000 ft from the shore in order to place the inlet in water about 25 ft deep. Such intakes have recently cost $50–$60 per foot in addition to the cost of the pipe, valves, the suction well, and other accessories.

Advances in the Use of Fluorspar for Fluoridation

F. J. Maier

A contribution to the Journal by F. J. Maier, San. Engr., Div. of Dental Health, USPHS, Dept. of Health, Education & Welfare, Washington, D.C.

IN 1945, sodium fluoride was first added to potable water in controlled amounts to produce a level of 1.0 ppm fluoride. Since then, fluoridation has been amply demonstrated to be beneficial in reducing dental caries and to produce no harmful effects. At present, more than 34,000,000 persons living in 1,775 United States communities are using an artificially fluoridated water supply.

Inasmuch as fluorspar is by far the least expensive commercially available fluoride compound, it would be a distinct advantage if it could be used for water treatment. Unfortunately, because of its insolubility in water, it has long been impossible to use it. Methods of using fluorspar in water treatment have been developed, however, and are described in what follows.

Sources and Properties

Fluorspar is the principal source of commercial fluoride compounds, although known deposits of phosphate rocks (apatites) may contain more fluorides. Certain technical and economic problems must still be overcome if apatites are to compete successfully with fluorspar as a source of fluorides. Cryolites have an even higher fluoride content, but deposits of these minerals are relatively very small.

Fluorspar is a mineral containing varying amounts of calcium fluoride. Pure calcium fluoride contains 51.1 per cent calcium and 48.9 per cent fluoride. Raw fluorspar may contain as little as 30 per cent calcium fluoride, but such a low grade cannot be used commercially without some refining. Commercial grades of fluorspar usually contain 85–98 per cent calcium fluoride. Pure fluorspar is a lustrous, glasslike material almost always translucent or transparent, and may be clear or any color of the spectrum. Deposits often occur in masses of very pure crystalline material mixed with pieces of various contaminants. Deposits occur in every part of the world, and there is substantial commercial production in several countries. The largest deposits so far found are in southern Illinois and northeastern Kentucky, an area comprising 700 sq mi, where there is a reserve of fluorspar sufficient to supply the needs of water plants for the next 20 years at the present rate of consumption. Smaller deposits are found in some of the western states, notably Colorado, Nevada, Montana, and New Mexico.

Fluorspar ore is usually mixed with many other rocks which must be separated from it before it is commercially acceptable, and must be subjected to

elaborate separation techniques which include washing, screening, gravity separation by jigs and tables and flotation. In addition to the usual harmless impurities—calcium carbonate, silicon dioxide, clay, and sand—there are also harmful impurities, including barium sulfate, lead sulfide, zinc sulfide, iron sulfide, and many other compounds of lead, zinc, and iron. The sulfides are often found in such quantity that they can be economically recovered from the ore.

Fluorspar must be low in silica and most other impurities for the manufacture of hydrofluoric acid and other fluoride compounds. This degree of purity can be obtained only by a special purification process, which usually includes flotation.

Uses in Water Treatment

Fluorspar is used in water fluoridation in either of two ways: (1) the mineral is dissolved at the water plant and fed as a solution, or (2) it provides the principal raw material in the manufacture of the various fluoride compounds that can be fed directly either as a liquid or solid. The primary compound manufactured from fluorspar is hydrofluoric acid. This is used in the preparation of most fluoride salts. This acid is obtained by acidulation of fluorspar with sulfuric acid:

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2HF$$

Hydrofluoric acid could be used (and was once used in at least one municipal water plant) directly, but it is usually too difficult to handle in water plants. Instead, the acid usually is used to make other compounds, which can be used directly. These include sodium fluoride.

Advantages of Fluorspar

It is by far more economical to dissolve the fluorspar at the plant, because fluorspar is less expensive than any other available fluoride compound. Sodium silicofluoride is three times as expensive; ammonium silicofluoride is three and one-half times as expensive; sodium fluoride is six and one-half times as expensive; magnesium silicofluoride is seven times as expensive; and hydrofluosilicic acid is nine times as expensive.

The use of fluorspar at the plant makes necessary a means for dissolving calcium fluoride, which is almost insoluble in water. It has long been known, however,[1] that calcium fluoride is soluble in strong acids or in solutions of aluminum compounds. It is more expensive to dissolve fluorspar in strong acids than it is to use the commercially prepared compounds, however. The use of solutions containing aluminum compounds is considerably more practical, in that one of the chemicals routinely employed in water plants as a coagulant is alum (aluminum sulfate) and it has been found that by varying the concentration of alum in solution, any desired quantity of fluoride can be obtained from fluorspar.

Direct Use

In a saturated fluoride solution, the fluoride concentration is about one tenth the alum concentration—that is, a 10 per cent alum solution contains approximately 1 per cent fluoride, and a 30 per cent alum solution produces a saturated fluoride solution containing approximately 3 per cent fluoride (30,000 ppm fluoride ion). Any fluoride strength between these extremes can be obtained by changing the concentration of alum.

Before a saturated fluorspar solution can be attained with alum, the following conditions must be satisfied:

1. Sufficient time must be provided for dissolving—usually about 2 hr at ordinary room temperatures (above 60°F).
2. An excess of fluorspar must always be present in the alum solution.
3. Vigorous stirring must be continued during the dissolving period.

Bel Air Plant

All of these conditions can be met if the dissolving tank is properly designed. The first such tank,[2] installed at the Bel Air, Md., water plant in July 1956, is 2 ft in diameter and 4½ ft high. Its capacity is about 75 gal. A circular weir around the inside of the tank provides a means for collecting and removing the dissolved fluoride and alum solution, which rises through the bed of fluorspar in the bottom of the tank. A central tube of stainless-steel pipe is fixed in the middle of the tank to support the mixer, and a cone is attached to the bottom of the pipe.

The device is placed near the source of alum solution. A small solution feeder previously used for feeding alum solution into the raw water is so arranged that it discharges into the central tube of the dissolver instead. The dissolver is charged with about 300 lb of fluorspar and the alum solution is made up by dissolving about 50 lb of alum in 50 gal of water, forming an alum solution of approximately 11 per cent strength. By adjusting the alum feed rate, 1.0 ppm fluoride can be fed into the raw water with 10 ppm alum. At these ratios, the dissolver can fluoridate up to 6 mil gal of water for each 100 lb of fluorspar. After 6 mil gal has been treated, an additional 100 lb of fluorspar is added to the tank to insure a constant fluoride level and provide a reserve. A clear effluent can be obtained from a dissolver of this size at upflow rates of 555 ml/min. This is equivalent to treating 2.3 mgd (1,610 gpm) with 1.0 ppm fluoride. The rate can be increased to 666 ml/min, which is sufficient to treat 2.8 mgd (1,940 gpm) at 1.0 ppm fluoride, but the effluent from the tank is slightly cloudy. The cloudiness of the solution is caused by calcium sulfate (gypsum) particles formed by the reaction between calcium fluoride and aluminum sulfate. At the lower rate (less than 555 ml/min) no visible calcium sulfate particles are suspended.

Calcium sulfate is produced at the rate of 1.7 lb for each pound of fluorspar dissolved in an alum solution. This must be removed from the tank whenever more fluorspar is added; otherwise the tank would fill up with solids. At Bel Air this removal is accomplished by siphoning off a slurry of calcium sulfate until enough room is provided for an additional 100 lb of fluorspar.

The equipment designed for Bel Air is considered to be particularly adaptable for smaller water plants to provide a fluoride residual of 1.0 ppm at rates of delivery of less than 1,600 gpm (2.3 mgd). Treatment plants of this size are usually equipped with proportionate solution feeders for alum solutions. In such instances, two alum solution feeders must be available. The alum feeder that serves the fluorspar dissolver is adjusted to deliver the minimum alum concentration necessary for coagulation (at Bel Air this was 10 ppm). Any additional alum required must be fed with another

solution feeder which discharges directly into the raw water—not into the fluorspar dissolver. If a reduction in fluoride dose is desired, it may be accomplished by either of two methods. One is to control the amount of alum solution fed, keeping the concentration constant; the other method, which is more cumbersome, requires a reduction in the one alum concentration (thereby changing the amount of fluorspar dissolved and discharged) and a proportionate increase in the quantity of the supplemental alum solution fed in order to supply the same total alum dose.

Suitability for Larger Plants

One possible disadvantage of the Bel Air equipment in larger plants would be the difficulty of removing the larger quantities of calcium sulfate formed in the dissolver. The small quantities produced at Bel Air are disposed of easily by siphoning them from the dissolver into a floor drain and thence into the nearby creek. This chore must be performed only about once a month. It would be a laborious process if large quantities were involved. Dumping 100-lb bags of fluorspar into the dissolver once a month is not particularly difficult, but it could be a serious problem if more frequent additions and larger quantities were necessary. For these reasons the design of the fluorspar dissolved at Bel Air is not ideally suited for larger treatment plants. Accordingly, a revision was undertaken which was intended to overcome these objections and which could be scaled upward to accommodate almost any size of plant.

Unit for Large Plants

An opportunity to build, install, and test an installation for larger plants was afforded by a leading producer of fluorspar, who contributed the apparatus to the water utility serving Rosiclare and Elizabethtown, Ill., and sufficient fluorspar to fluoridate the supply for the next 5 years. Drawings and specifications of the installation had to be reviewed and approved by the Illinois State Health Department. The city authorities voted to fluoridate their water and agreed to have the water plant employees trained to maintain and operate the equipment. The fluorspar dissolver for this plant is shown in Fig. 1 and 2.

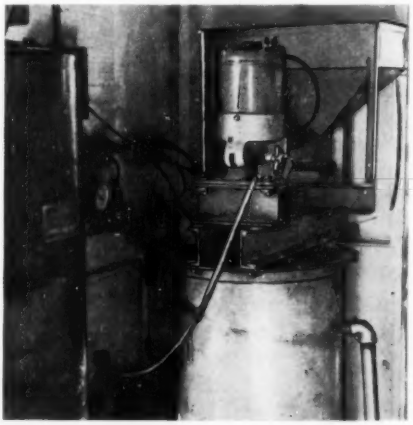


Fig. 1. Fluorspar Dissolver

A schematic drawing of the complete installation is given in Fig. 2.

Three fundamental changes were incorporated in the design:

1. An existing volumetric dry feeder for alum was the source of the alum solution and a constant portion of this solution was metered into the fluorspar dissolver. Consequently, in order to change the fluoride dose, provision had to be made for controlling the alum concentration from the dry-feeder dissolving chamber. This was done by

careful regulation of the amount of water entering the dissolving chamber of the alum feeder. On the other hand, if a change in the quality of the raw water made it necessary to adjust the alum dose, leaving the fluoride level the same, the alum feeder was reset and the amount of water flowing to the dissolving chamber was changed to produce the same alum solution strength as before.

2. The rate at which alum solution is introduced into the dissolving chamber was selected and fixed experimentally from observations of the hydraulic separation of fluorspar and calcium sulfate. If this rate is constantly maintained for a dissolver of a given surface area, the amount of calcium sulfate discharged should equal the amount formed. The calcium sulfate would, of course, be discharged into the water along with the alum solution and dissolved fluoride. The addition of calcium sulfate into the water presents no difficulties in subsequent treatment processes; it is, in fact, a slight advantage in that it provides additional nuclei for floc formation.

3. A volumetric dry feeder is provided to feed fluorspar continuously. This is done in order to facilitate the addition of fluorspar to the dissolver and to provide a constant concentration of dissolved solids in the dissolver. The latter is important because the time required to raise the solids "blanket" to the level of the weir is directly proportional to the distance it is raised. Consequently, in fixing the optimum solids-contact rate for alum solution for a comparatively constant period of operation, the same distance between the weir and the solids blanket must be maintained when the dissolver is not operating. This is done by equating the amounts of fluorspar added and dissolved, and the amounts of calcium sulfate formed and discharged.

In order to accomplish these three objectives, several pieces of equipment were added to the Rosiclare plant (Fig. 2). The existing volumetric feeder * was mounted on a larger (55-gal) dissolving chamber, and the entire assembly was mounted on a platform scales. In order to insure complete dissolving of the alum, the water jet agitators are supplemented by an electric mixer. In addition, the water entering the dissolving chamber is controlled by the following devices installed on the water line: a shutoff valve, a solenoid valve, a strainer, pressure regulator, pressure gage, water meter, needle valve, rate of flow indicator, vacuum breaker, and flexible connector. Most of this apparatus is included to control the flow of water into the dissolver as constantly and as accurately as possible.

On the outlet from the alum-dissolving chamber, a flow splitter, consisting of two 3-in. tees in series, permits part of the effluent to flow directly into the raw-water channel and part to flow to the intake of the suction line of the alum solution feeder. The latter delivers a constant quantity of alum solution into the central column of the fluorspar dissolver.

The fluorspar dissolver is fitted with an inner cone housing an electrically driven turbine mixer. The central cone also provides a means for introducing fluorspar into the dissolver from a vibratory volumetric feeder mounted on top of the dissolving tank. The feeder is fitted with a hopper, which holds 100 lb of fluorspar, and

* Universal; a product of Omega Machine Co., Division of B-I-F Industries, Providence, R.I.

a rheostat for changing the rate of feed.

Operation of Large Unit

The plant is started by turning on the raw-water pump, which delivers 460–570 gpm (depending on the river stage) of Ohio River water into the mixing channel. There the alum and dissolved fluorspar are added, together with a small amount of lime, for pH control. The treated water passes a

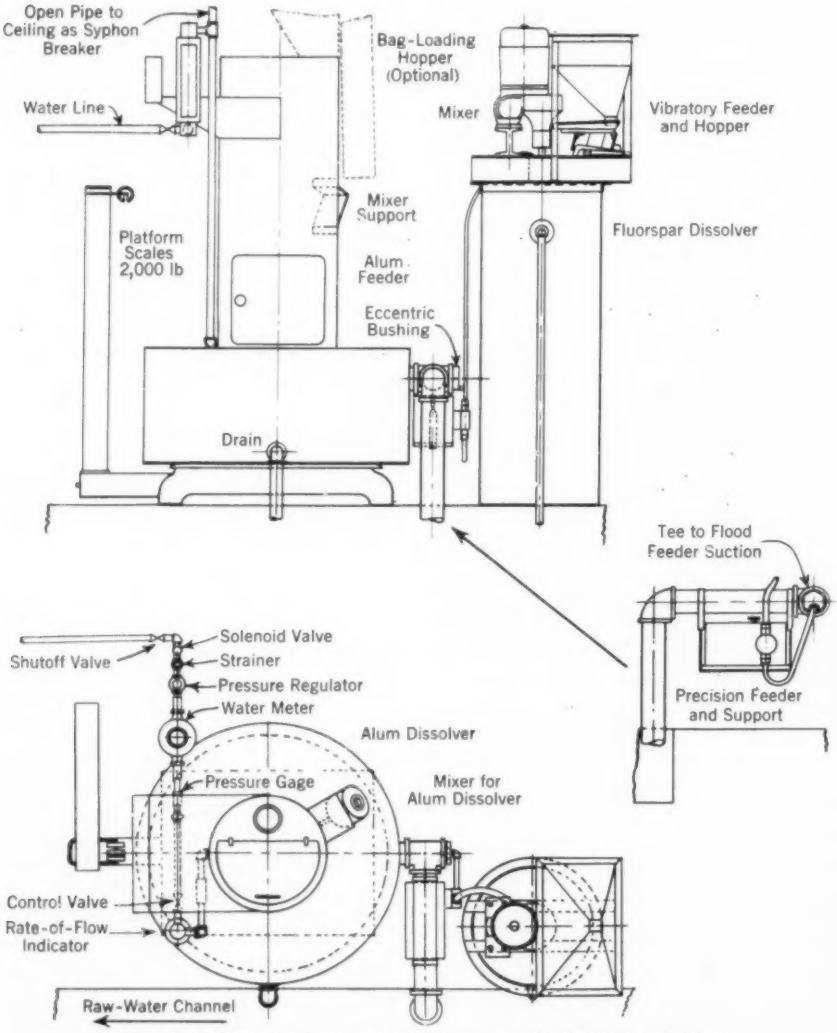


Fig. 2. Schematic Drawing of Fluorspar Dissolver Installation

This unit, designed for larger plants, is now in use at the Rosiclare plant.

series of flocculators, and the subsequently formed floc is settled out in a 180,000-gal sedimentation basin. From there the water flows through two 58-sq ft filters into a 60,000-gal clear well. High-lift pumps raise the treated water to a 100,000-gal elevated storage tank.

A float switch on the sedimentation tank automatically starts and stops the raw-water pump, flocculators, four chemical feeders, two solenoid valves on the water lines to the dissolving chambers, and two electric mixers.

fluoride loss from the treated water increases, the alum concentration increases. At Bel Air, for instance, almost one-third of the added fluorides are lost when the alum concentration is 100 ppm. This effect is not the same for all waters or under all conditions for the same sources of water. Different types of turbidity have different effects on fluoride removal when the water is coagulated with alum.

Examples of how some of these variables are used to calculate the alum solution concentration necessary to ob-

TABLE 1

*Fluorspar Feeding System at Rosiclare Plant**

Desired Fluoride Addition *ppm*	Fluoride Feed Rate *gr/min*	Fluorspar Solution *per cent*	Alum Fed *ppm*	Alum Feed Rate *lb/hr*	Alum Solution		
					Solution Strength *per cent*	Feed Rate	
						lb/hr	*gpm*
0.3	0.567	0.075	25	6.25	0.75	835	1.65
1.0	1.890	0.252	25	6.25	2.52	248	0.50
1.1	2.070	0.276	25	6.25	2.76	226	0.45
0.3	0.567	0.075	65	16.20	0.75	2,160	4.30
1.0	1.890	0.252	65	16.20	2.52	645	1.30
1.2	2,260	0.302	65	16.20	3.02	537	1.10
0.3	0.567	0.075	100	25.00	0.75	3,330	6.60
1.0	1.890	0.252	100	25.00	2.52	990	2.00
1.3	2.450	0.328	100	25.00	3.28	763	1.50

* Raw-water rate, 500 gpm; dissolver upflow rate, 750 ml/min.

It is necessary to provide means for the accurate feeding of both alum and fluorspar at different raw-water pumping rates and under a wide variety of conditions of raw-water quality. The alum concentrations required may vary from 10 to more than 100 ppm, depending on the condition of the river. The fluoride content may vary from almost zero to more than 2.0 ppm, depending on nearby discharge of waste water from fluorspar-processing plants. In addition, it was known that, as the

tain 1.0 ppm fluoride in the treated water are shown in Table 1. From these examples, the strength of the alum solution can be obtained for any desired alum concentration or fluoride addition. A nomogram for the use of the water plant operators to obtain approximately this alum solution strength is given in Fig. 3. With the nomogram one may obtain the correct water flow rate into the alum dissolver to obtain various alum and fluoride concentrations.

So far the dissolver has produced fluoride concentrations in the predicted ratio of 10,000 ppm fluorides for each 10 per cent level of alum concentration. With the apparatus described the water at Rosiclare has been fluoridated to a level of 1.0 ppm since Oct. 22, 1958.

The automatic removal of calcium sulfate depends on the upflow rate of the alum solution and the level of the solids below the discharge weir in the fluorspar dissolver. This water plant is operated three times each day for various periods of time depending on the rate of water consumption. At a rate of 650 ml/min, the solids rise a maximum of 10 in. requires at least 2 hr. If none of the three operating periods in any one day lasts as long as 2 hr, then no solids are discharged, provided that the initial solids level was 10 in. or more below the weir. If no

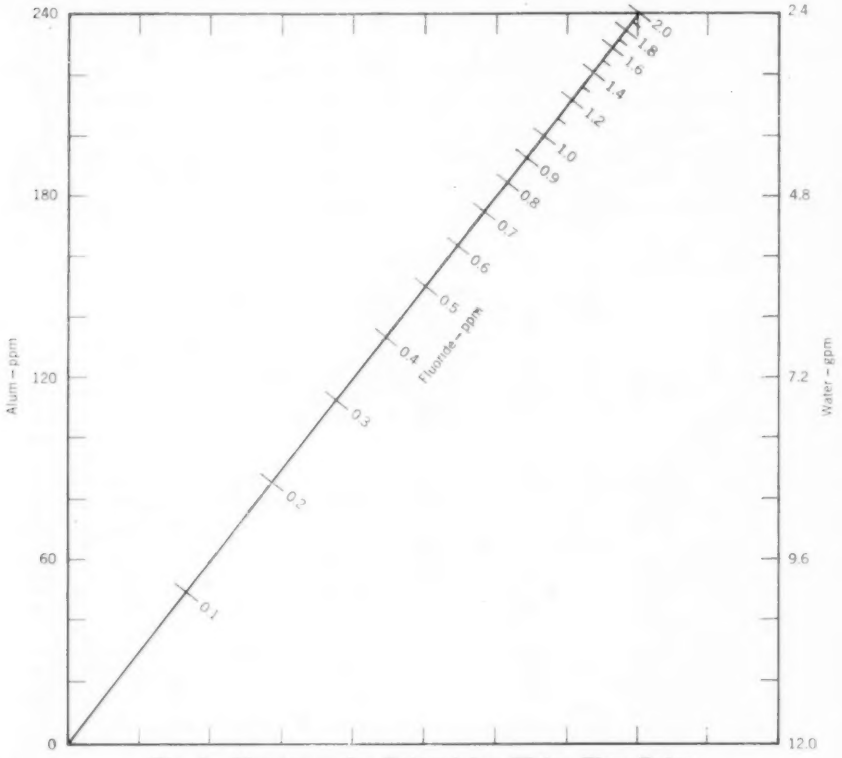


Fig. 3. Nomogram for Determining Water Flow Rates

To use the nomogram, find the alum concentrations on the left-hand scale and lay a straightedge through it and the desired fluoride concentration on the diagonal scale. The correct water flow rate to the dissolver may then be read where the straightedge crosses the right-hand scale. The nomogram is designed for an upflow rate of 750 ml/min.

solids are discharged for several days, they accumulate until the level is less than 10 in. and then begin to be discharged in less than 2 hr. The rate of rise of the alum solution must therefore be selected according to the average duration of the various operating periods. If the rate is too low, the solids accumulation becomes too deep and clogs the mixer and the lower outlet of the cone, preventing alum solution from entering the dissolver. If, on the other hand, the rate is too high, an excessive amount of fluorspar is carried up along with the calcium sulfate and lost. Ideally, that upflow rate should be used which will remove each day the same amount of calcium sulfate as was formed, without carrying over any undissolved fluorspar. At present an upflow rate of 825 ml/min is used whenever two or more operating periods per day are prolonged for as much as 110 min. Under these conditions, the sludge blanket rises 16 in. in about 85 min to provide an average period of sludge discharge of 25 min. At this upflow rate, and with a 25 per cent alum solution, the dissolver is capable of fluoridating up to 8.0 mgd at 1.0 ppm.

Conclusion

It is believed that the apparatus described can be scaled upward to accommodate the largest water treatment plants in the country. Such necessary modifications as a tank of larger diameter and a means for proportioning and introducing fluorspar could be incorporated without much difficulty.

In the United States 72,000,000 persons are served by water utilities using coagulants in their treatment plants. This represents almost three-fourths of the population served by public water supplies. About 60,000,000 of these people live in 325 communities whose populations are greater than 25,000. If it is assumed that at least 1 lb of fluorspar is required to fluoridate the water consumed by one person in a year, then there is a potential additional use of more than 70,000,000 lb of fluorspar per year for fluoridation.

References

1. *Encyclopedia of Chemical Technology.* Interscience Publishers, Inc., New York (1951).
2. MAIER, F. J. & BELLACK, E. Fluorspar for Fluoridation. *Jour. AWWA,* 49:34 (Jan. 1957).

Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction

Jonathan L. Tuepker and Herbert O. Hartung

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Jonathan L. Tuepker, Supt. of Purification, and Herbert O. Hartung, Vice-Pres. & Mgr. of Production, both of the St. Louis County Water Co., St. Louis, Mo.

THE total amount of hardness precipitated during cold-water lime softening can be materially increased when the softening reactions occur in the presence of 2 per cent or more of previously precipitated calcium carbonate slurry. Similarly, the amount of hardness precipitated, per unit of lime added, can be materially increased for any lime dose that is not in excess of the amount of lime equivalent to the raw-water alkalinity plus the amount of lime equivalent to the magnesium in the raw water. Such improved softening may be either calcium or magnesium reduction, or both. Figures 1–3 show the results of a laboratory study of improved hardness reduction of Meramec River water. These results were obtained when softening occurred in the presence of approximately 10 per cent, by weight, of washed, reagent grade, precipitated calcium carbonate. When the lime dose was chemically equivalent to the raw-water alkalinity plus 17.12 ppm, the improved total hardness reduction was 30 ppm, of which 10 ppm was calcium hardness and 20 ppm magnesium hardness.

Past Studies

Sperry,[1] in 1919, was one of the first to report that the large amounts of softening sludge returned to the lime mixing chamber had a very important effect in reducing the residual total alkalinity and magnesium content of the water. When the returned sludge (86 per cent calcium carbonate) was 5 per cent by weight in the mixing chamber, he found that magnesium hardness precipitation was increased 28 per cent, and the normal carbonate alkalinity was reduced to 33 ppm. Sperry abandoned his experiments because of his inability to return sludge continuously in sufficient quantity.

Pilot plant studies of Meramec River water were conducted during 1941 and 1942 at the St. Louis County Water Co.[2] These studies showed that when the lime dose was equivalent to the raw-water alkalinity, as much as 30 ppm of additional hardness precipitation was obtained by softening in the presence of more than 2 per cent, by weight, of previously precipitated slurry. These studies did not differentiate between calcium and magnesium hardness reduction. It was noted, however, that slurry which was not predominately calcium carbonate, containing ferric coagulant or turbidity, was much less effective in causing improved softening.

The 15-mgd South County plant of the St. Louis County Water Co., con-

structed in 1956, has confirmed these pilot plant studies.[3] When the concentration of suspended solids in the contact softener was increased from near zero to more than 2 per cent by weight, residual calcium was reduced from 15 ppm to 3 ppm as Ca (37.5–7.5 ppm as $CaCO_3$). In addition, magnesium

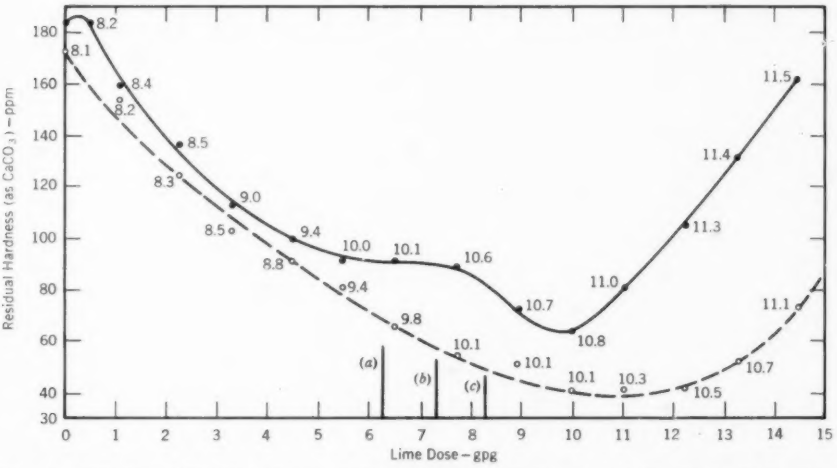


Fig. 1. Effects of Washed, Reagent Grade Calcium Carbonate on Hardness Reduction in Lime-Softened Meramec River Water

The solid curve represents the residual hardness in the absence of calcium carbonate slurry. The dashed curve shows the residual hardness when calcium carbonate slurry was present in a concentration of 10 per cent by weight and when the contact time was 3 hr. The filled and open circles on or near the curves indicate approximate pH values. At pH 10.8 on the solid curve, the phenol alkalinity was 33 ppm, and the methyl orange alkalinity 44 ppm; at pH 10.1 on the dashed curve, above 10 gpg, the phenol alkalinity was 15 ppm, and the methyl orange alkalinity 30 ppm. Vertical lines a, b, *and* c *represent the raw-water alkalinity equivalent, raw-water alkalinity equivalent plus 1 gpg (17.12 ppm), and raw-water alkalinity plus 2 gpg (34.24 ppm), respectively. The lime used contained 92 per cent calcium oxide.*

softening was increased on an average of 3 ppm as Mg (12 ppm as $CaCO_3$) when the concentration of suspended solids was more than about 4.5 per cent by weight and when the lime dose equaled the raw-water alkalinity.

In 1944, Walker,[4] using 1.5 per cent slurry by weight, observed from his jar test experiments on split-lime treatment that "prolonged rapid agitation of the mixture being treated appears to be the most efficient means of producing a balanced water. . . . If magnesium hydrate–bearing slurry is used as the contact media, the hardness of the water will be increased as the pH drops." McCauley and Eliassen[5] reported their experimental work in 1955. They found that a value of 15–25 ppm of residual calcium hardness can be obtained easily

> . . . by reacting the raw water with lime and soda ash and stirring rapidly in the presence of 3–5 per cent preformed cal-

cium carbonate crystals at a pH of about 9.8–10.2. Under such circumstances about 20 min is required to cause the chemical reactions to reach a state close to equilibrium. Shorter reaction periods may be used with higher concentrations of preformed crystals. Some magnesium removal may also be noted.

ence of silica, will often upset actual or apparent equilibrium conditions and cause hot-water pipe and heater scaling.[7] For these reasons, several investigators have advocated the removal of magnesium by excess lime or split treatment–softening methods, followed

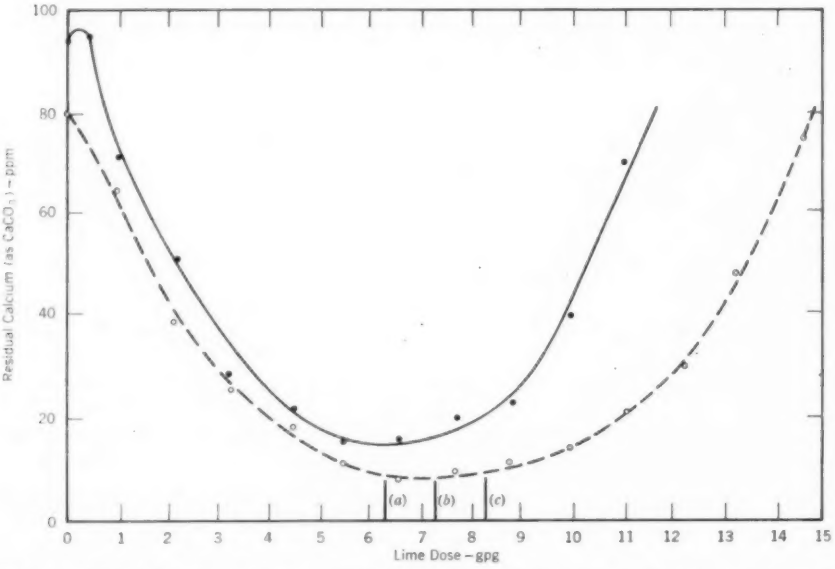


Fig. 2. Effects of Washed, Reagent Grade Calcium Carbonate on Calcium Reduction in Lime-Softened Meramec River Water

The solid curve represents the residual calcium in the absence of calcium carbonate slurry. The dashed curve shows the residual calcium when calcium carbonate slurry was present in a concentration of 10 per cent by weight and when the contact time was 3 hr. Vertical lines a, b, *and* c *represent the raw-water alkalinity equivalent, raw-water alkalinity equivalent plus 1 gpg (17.12 ppm), and raw-water alkalinity equipment plus 2 gpg (34.24 ppm), respectively. The lime used was 92 per cent calcium oxide.*

In 1955, Calise, Duff, and Dvorin [6] also reported similar conclusions from their laboratory experiments.

Calcium stabilization of lime-softened water is much more readily obtained than magnesium stabilization. In addition, changes in temperature or small changes in pH, especially in the pres-

by additional processing for calcium stabilization. For example, in 1942, Hoover [8] proposed that "lime should be used in quantities large enough to precipitate as much magnesium as possible, even though the treated water may contain from 20 to 30 ppm of caustic alkalinity." He also stated that

the excess lime required to precipitate the magnesium should be carbonated and, then, the carbonated effluent contacted in a sludge blanket device with magnesium-free crystallized calcium carbonate sludge. Cherry,[9] in the plant at Cedar Rapids, Iowa, was able to reduce magnesium to 8.0 ppm (as Mg) than 8 ppm oxygen, excess lime treatment along with alum should first be used to effect a maximum removal of magnesium and silica. This should be followed by recarbonation to a pH of 9.6–10.0, converting all, or nearly all, of the hydroxide to carbonate; and final stabilization should be secured by addition of glassy sodium phosphate.

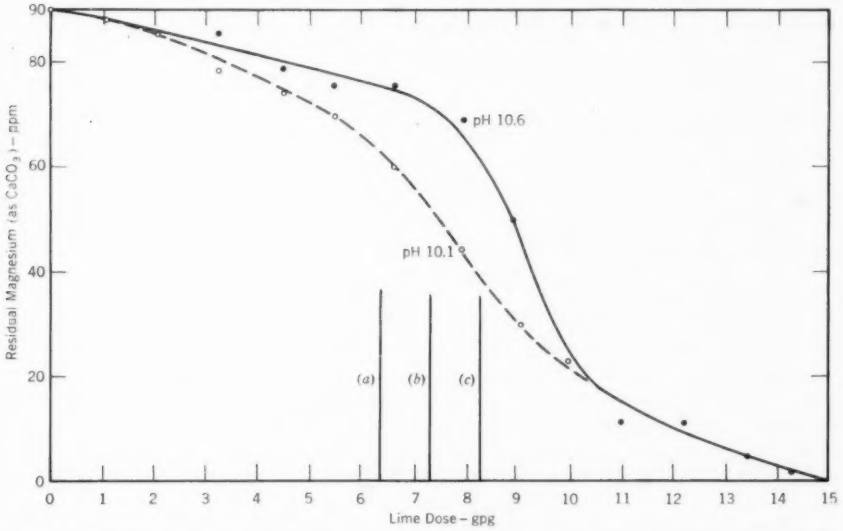


Fig. 3. Effects of Washed, Reagent Grade Calcium Carbonate on Magnesium Reduction in Lime-Softened Meramec River Water

The solid curve represents the residual magnesium in the absence of calcium carbonate slurry. The dashed curve shows the residual magnesium when calcium carbonate slurry was present in a concentration of 10 per cent by weight and when the contact time was 3 hr. At pH 10.6, the phenol alkalinity was 40 ppm, and the methyl orange alkalinity 71 ppm; at pH 10.1, the alkalinity was 17.36 ppm. Vertical lines a, b, *and* c *represent the raw-water alkalinity, raw-water alkalinity plus 1 gpg (17.12 ppm), and raw-water alkalinity plus 2 gpg (34.24 ppm), respectively. The lime used contained 92 per cent calcium oxide.*

and alkalinity to less than 40 ppm by a combination return sludge and 30–70 per cent split-treatment processing. Rice [10] concluded that:

To minimize trouble from magnesium silicate deposits in waters carrying more

Present Studies

The possibility that magnesium as well as calcium stability can be obtained in a suspended solids–contact softening basin, when slurry concentrations and mixing times are sufficiently large, was indicated by some

of the previously mentioned studies and experiences. The advantage of bringing both the calcium and magnesium lime-softening reactions to completion without the need for subsequent recarbonation or other chemical additions is self-evident. This article reports studies still in progress to determine the factors necessary to reduce the magnesium hardness in Meramec River water to an amount that will be stable. The studies utilize quantities of softening slurry in jar experimentation and in a suspended solids–contact basin. A previous article [11] discussed calcium carbonate stabilization of lime-softened water with retained calcium carbonate slurry.

The present softening studies of Meramec River water have been separated into three phases:

1. Effect of varying slurry concentrations on magnesium reduction
2. Effect of varying mixing times on magnesium reduction, when softening occurs in the presence of softening slurry
3. Effect of different slurries on magnesium reduction.

Experience at the St. Louis County Water Co. has shown that magnesium in softened Meramec River water will not precipitate in the distribution system or cause scale in 140°F domestic hot-water heaters when the amounts of magnesium are less than those

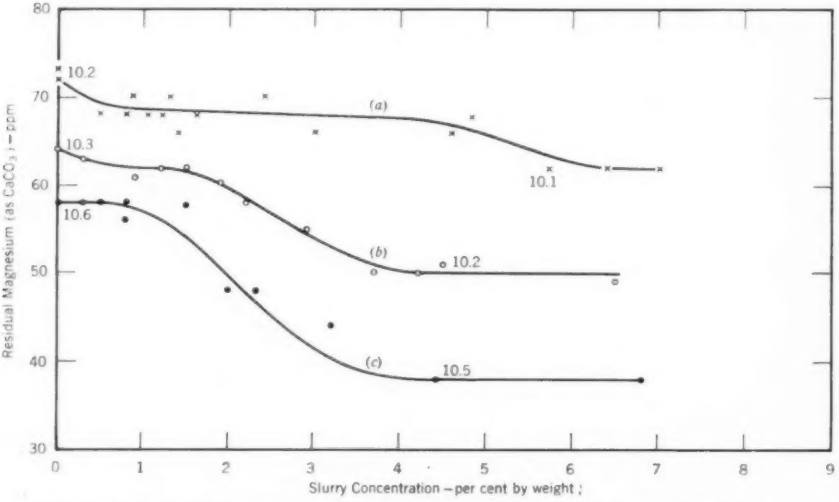


Fig. 4. Effects of Retained Softening Slurry on Magnesium Reduction During Lime Softening

Curve a *was the result when the lime added was equivalent to the raw-water alkalinity. In Curve* b, *the lime added was equivalent to the raw-water alkalinity plus 17.12 ppm. In Curve* c, *the lime added was equivalent to the raw-water alkalinity plus 34.24 ppm. The characteristics of the raw water were approximately as follows: pH, 8.2; phenol alkalinity, 0 ppm; methyl orange alkalinity, 142 ppm; calcium, 76 ppm; magnesium, 78 ppm; total hardness, 154 ppm; and temperature, 58°F. The mixing time was 60 min.*

shown in Table 1. These amounts have been determined empirically by routinely measuring magnesium in the inlet and outlet pipes of a hot-water heater and by immersing samples of softened water for 24 hr in a laboratory hot-water bath. The results of the study on magnesium stability, reported herein, have been evaluated by comparing them to the maximum allowable magnesium quantities shown in Table 1.

To produce softened water in the pH range given in Table 1 (pH 9.0–9.8), the lime treatment doses had to be limited approximately to the values between the raw-water alkalinity equivalent and the same equivalent plus 34.24 ppm. Obviously, the pH of the softened water for any lime dose will depend on the completeness of precipitation of the softening products. Also, softening in the presence of previously precipitated slurry, to produce calcium and magnesium stability, will result in a lower pH of water than when maximum softening is not obtained. From operating experiences at softening plants, it has been observed that the coagulation and chlorination of Meramec River water required after softening will cause the pH of the finished water to be 0.4–0.7 less than the pH of the effluent from the suspended solids–contact softener.

TABLE 1

Approximate Amounts of Maximum Allowable Magnesium in Lime-Softened Meramec River Water Which Will Not Precipitate in 140°F Domestic Hot-Water Heaters

pH of Water at 25°C	Mg (as $CaCO_3$) *ppm*
9.0	65
9.2	57
9.4	51
9.6	45
9.8	40

TABLE 2

Relationship Between Slurry Concentration for Best Magnesium Removal and Lime Dose for Softening Meramec River Water, When Mixing-Contacting Time is 60 min

Lime Dose	Retained Slurry Concentration *% by weight**
Equivalent to raw-water alkalinity	6
Equivalent to raw-water alkalinity plus 17.12 ppm	4.5
Equivalent to raw-water alkalinity plus 34.24 ppm	4

* Approximate values.

Effect of Slurry Concentration on Magnesium Reduction

It has been demonstrated that magnesium precipitation is increased if lime softening is in the presence of appreciable quantities of previously precipitated softening slurry when the lime treatment is equal to, or somewhat in excess of, the raw-water alkalinity equivalent. Retained slurry has been found to be of very little value for magnesium reduction when the lime treatment is appreciably in excess of the raw-water alkalinity plus the magnesium equivalent.

A typical jar test study illustrating the value of retained slurry for magnesium reduction is shown in Fig. 4. Varying amounts of slurry were added to 1-liter quantities of Meramec River water to which lime for softening was also added. The slurry used in the jars was generated in a 4-gpm pilot plant suspended solids–contact basin with the same water and lime dose as those in the jars. Thus, a different slurry was generated for each lime dose. Figure 4 illustrates that the amount of slurry required for maxi-

mum magnesium removal is dependent, in part, on the amount of lime used in the treatment. The smaller lime doses required the most retained slurry for best magnesium removal. Table 2, a summary of Fig. 4, shows the relationship between the slurry concentration required for maximum magnesium precipitation and the various lime doses used for softening Meramec River water when the mixing-contacting time was 60 min.

Data from the South County plant of the St. Louis County Water Co. have also confirmed that increased slurry concentrations result in increased magnesium precipitation. Typical data are given in Table 3. The best magnesium reduction was always obtained when the slurry concentration was 5 per cent or more.

Effect of Mixing Time on Magnesium Reduction

In general, these softening studies have also shown that the mixing time required for magnesium precipitation is somewhat inversely related to the slurry concentration. Within limits, the smaller slurry concentrations required longer mixing times, and, similarly, the larger slurry concentrations required less mixing. There seems to be a minimum slurry concentration less than which even very long mixing times will not cause additional precipitation.

The effect of mixing times, when the slurry concentration was 3 per cent by weight and the lime dose was equal to the alkalinity equivalent of the raw water plus 34.24 ppm, is shown in Fig. 5. Also shown are the following results:

1. Mixing times between 10 min and 60 min did not cause an increase in magnesium precipitation when there was no retained slurry present.

2. With 3 per cent retained slurry by weight, magnesium precipitation was increased when the mixing time was increased from 10 min to 20 min.

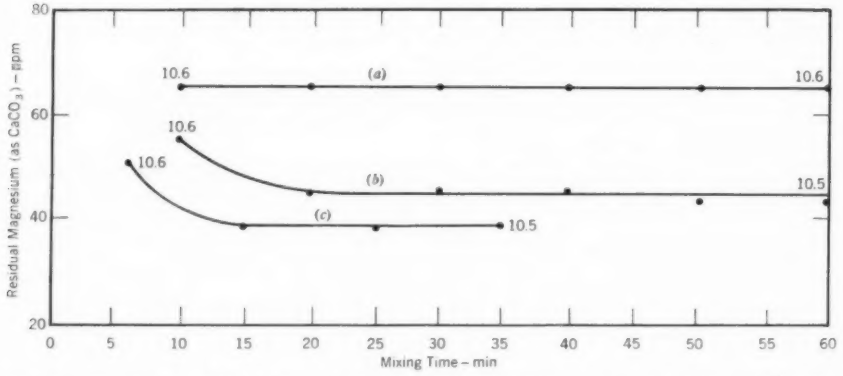


Fig. 5. Effects of Mixing Times and Slurry Concentrations on Magnesium Reduction

Curve a *shows the effects of mixing times when only lime was used. The effect of mixing times when lime was used with slurry in concentrations of 3 per cent by weight and 7 per cent by weight, are shown in Curves* b *and* c, *respectively. The lime dose was equivalent to the raw-water alkalinity plus 34.24 ppm. The raw water containued 76 ppm magnesium as calcium carbonate.*

3. With 3 per cent retained slurry by weight, magnesium precipitation was not increased when the mixing time was increased from 20 min to 60 min.

4. When the slurry concentration was 7 per cent by weight, a shorter mixing time was required for best magnesium removal than when the slurry was only 3 per cent by weight.

The effect of mixing times on magnesium removal was again demonstrated with the pilot plant suspended solids–contact unit. Water containing slurry was withdrawn from the center draft tube into a series of 1-liter beakers. These were mixed for various periods of time, after which the residual magnesium was determined. The results are shown in Fig. 6. Water was withdrawn when the slurry in the center draft tube was 2 per cent by weight and, again, when it was 7 per cent by weight. When the concentration of retained slurry was 7 per cent by weight, maximum magnesium precipitation was obtained after 5 min of additional mixing. When the slurry concentration was only 2 per cent by weight, about 25 min of additional mixing was required for maximum precipitation of magnesium.

TABLE 3

*Effect of Varying Slurry Concentrations on Magnesium Reduction in Meramec River Water, When Treated With an Alkalinity Equivalent of Lime**

Raw Water		Slurry Concentration % by weight	Residual Mg (as $CaCO_3$) ppm	Mg Reduction %
Alkalinity ppm	Mg ppm			
125	54	0	46	14.8
124	54	2	41	24.0
126	56	4	37	34.0
148	82	0	72	12.2
148	82	3	58	29.4
150	84	5	53	37.0
158	87	0	72	17.2
160	87	3	62	28.8
158	87	5	55	37.0
171	98	0	82	16.3
171	98	3	70	28.6
172	98	5	65	34.0

* Data are from the South County Treatment Plant, St. Louis County Water Co.

TABLE 4

Effect on Residual Magnesium of 30 min of Additional Mixing and Various Amounts of Slurry Added to Pilot Plant Effluent Water

Concentration of Slurry Added % by weight	Residual Magnesium* (as $CaCO_3$) ppm
0	76
1.5	70
3	62
5	56

* There was 80 ppm residual magnesium in the raw water and 76 ppm in the pilot plant effluent.

The importance of both adequate slurry concentrations and adequate mixing times for maximum magnesium removal was further demonstrated by adding to pilot plant effluent water various quantities of slurry. Samples of this water, with their respective amounts of slurry, were mixed for an additional 30 min on the jar test mixing machine, and more magnesium precipitation was obtained, as shown in Table 4. Contact time with slurry in the pilot plant unit was calculated to be approximately 5 min. Therefore, total contact time was about 35 min. From this study, the following observations were made:

1. There was no change in residual magnesium when the pilot plant effluent water was mixed for an additional 30 min without adding slurry.

2. When the slurry concentration was 1.5 per cent by weight in the jars, and mixing was for an additional 30 min, the residual magnesium was reduced from 76 ppm to 70 ppm.

3. By increasing the slurry concentration to 5 per cent by weight, and also mixing for an additional 30 min,

the residual magnesium was reduced to 56 ppm.

These results are typical of other observations which indicate that for maximum magnesium removal, both slurry concentration and mixing time must be provided during the lime-softening processing. A slurry concentration of about 5 per cent by weight and a mixing time of about 30 min seem to be adequate.

In addition, experimentation has revealed that the various slurries affect magnesium precipitation differently.[13] Because of these differences, an exact specification of the amount of slurry required for maximum magnesium precipitation cannot be made. The slurry concentrations used in the experiments described earlier, were produced only with lime added to Meramec River water.

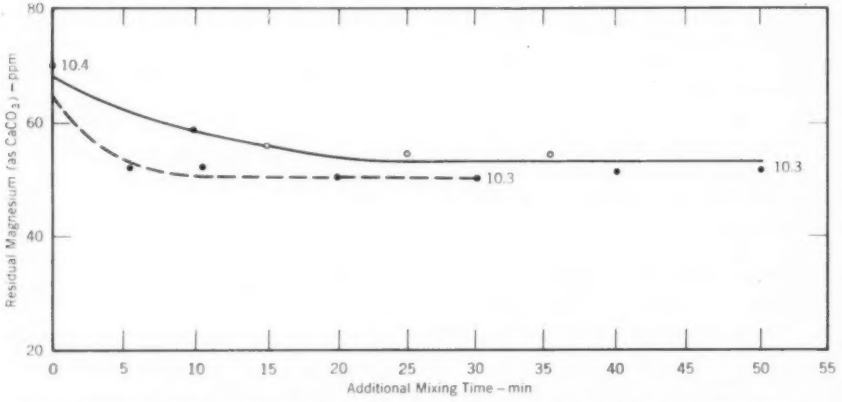


Fig. 6. Effect of Additional Mixing Times on Magnesium Reduction in Pilot Plant, Draft Tube Water

The solid and dashed curves show the results when the slurry in the draft tube was 2 per cent by weight and 7 per cent by weight, respectively. The lime dose was equivalent to the raw-water alkalinity plus 20.54 ppm.

Effect of Different Slurries on Magnesium Reduction

Lime-softening slurries from different waters, or those produced by different lime doses, are not identical. Furthermore, physical characteristics of slurries from different softening plants are not the same, as was shown by Black.[12] Slurries from Meramec River water that contain various amounts of activated silica, coagulant, or turbidity, also have been found to differ in their physical characteristics.

Experience with the pilot plant suspended solids–contact unit and with the full-scale softening-plant suspended solids–contact basin, has shown that if the slurry is bulky, containing appreciable amounts of magnesium or coagulant, the retained slurry often cannot be accumulated to a concentration of 5 per cent by weight. In such instances, after the slurry reaches a concentration of about 1–2 per cent by weight, it overflows the basin at the same rate that it is precipitated.

Table 5 shows the residual magnesium found in waters softened with two different lime doses and various amounts of slurry, with and without activated silica. When activated silica was in the slurry, less magnesium precipitation was obtained.

Summary

From the lime-softening studies of Meramec River water, it has been determined that:

1. Magnesium precipiation, as well as calcium precipitation, by lime softening is increased when the softening occurs in the presence of circulating, previously precipitated lime-softening solids.

2. About 5 per cent retained slurry, without activated silica, coagulant, or turbidity, and a mixing time of about 30 min seem to be adequate for best magnesium precipitation in Meramec River water.

3. The amount of slurry required for maximum magnesium removal varies with the lime dose: the more the lime dose exceeds the raw-water alkalinity equivalent, the less the amount of suspended softening solids required. When the lime dose is equivalent to the raw-water alkalinity, the concentration of suspended solids required may equal or exceed 5 or 6 per cent by weight.

4. Water that has been lime softened in the presence of 5 per cent slurry, with a mixing time of more than 30 min, may not require recarbonation. In such an instance, the addition of chlorine required for disinfection and the coagulant required for clarification after softening, reduces the pH of the softened water so that the magnesium remains stable in hot-water heaters at 140°F.

5. A greater quantity of suspended softening solids is required for improved magnesium precipitation than for improved calcium precipitation.

6. The amount of suspended softening solids required for improved lime softening is also dependent on the characteristics and composition of the suspended solids. Iron, aluminum, magnesium, and activated silica in the lime-softening solids seem to lessen the

TABLE 5

*Effect of Different Slurries on Magnesium Reduction of Meramec River Water**

Lime Dose	Slurry % by weight	Residual Magnesium (as $CaCO_3$)—ppm	
		Slurry From Lime and Activated Silica	Slurry From Lime Only
Alkalinity equivalent plus 34.24 ppm	1.0	50	50
	2.0	46	46
	3.0	40	38
	4.5	36	30
Alkalinity equivalent plus 17.12 ppm	1.0	60	56
	2.5	52	50
	5.0	44	40
	6.5	44	36

* Contact time with the slurries was 1 hr.

TABLE 6

*Typical Analysis of Meramec River Water**

Item	Concentration ppm†
Turbidity	15‡
Dissolved solids	185
pH	8.0
Alkalinity	0–147
Total hardness	172
Calcium	96
Magnesium	76
Iron	0
Sodium potassium	4
Nitrates	2
Chlorides	5
Sulfates	19
Silica	7

* Characteristics of Meramec River water change rapidly with the intensity of rainfall. At times, concentrations may differ by more than 100 per cent from those listed.
† Except for pH value.
‡ Maximum concentration is 5,000 ppm.

effectiveness of the suspended solids as an aid to softening.

Conclusion

Magnesium very often can be reduced, by softening Meramec River water with lime in the presence of accumulated softening slurry, to an amount that will not precipitate in 140°F domestic hot-water heaters and will not require recarbonation. The lime dose for this purpose should not exceed the raw-water alkalinity equivalent plus 34.24 ppm. The slurry concentration for contacting should be about 5 per cent by weight and should be from softening products only, being virtually free of activated silica, coagulant, and turbidity. If large amounts of magnesium solids are accumulated in the slurry, and are not removed with the effluent water, the slurry becomes less effective as a softening aid. Mixing and contacting time for the softening reactions should be about 30 min.

References

1. Sperry, W. A. The Lime Softening of Water and the Use of the Sludges as an Aid Thereto. *Jour. AWWA*, 6:215 (Jun. 1919).
2. Hartung, H. O. Experience With Upflow-Type Basins. *Wtr. & Sew. Wks.*, 1:91 (Jan. 1944).
3. Hartung, H. O. Treatment Plant Innovations in St. Louis County, Mo. *Jour. AWWA*, 50:965 (Jul. 1958).
4. Walker, Donald. Split-Treatment Water Softening. *Jour. AWWA*, 36:675 (Jun. 1944).
5. McCauley, R. F. & Eliassen, R. Accelerating Calcium Carbonate Precipitation in Softening Plants. *Jour. AWWA*, 47:487 (May 1955).
6. Calise, V. J.; Duff, J.; & Dvorin, R. Chemical Reactions in Hot and Cold Treatment Units. *Jour. AWWA*, 47:665 (Jul. 1955).
7. Larson, T. E. The Ideal Lime-Softened Water. *Jour. AWWA*, 43:649 (Aug. 1951).
8. Hoover, C. P. Stabilization of Lime-Softened Water. *Jour. AWWA*, 34:1425 (Sep. 1942).
9. Cherry, A. K. Split-Treatment Method of Water Softening. *Jour. AWWA*, 47:393 (Apr. 1955).
10. Rice, Owen. Discussion—Stabilization of Lime-Softened Water. *Jour. AWWA*, 34:1446 (Sep. 1942).
11. Hartung, H. O. Calcium Carbonate Stabilization of Lime-Softened Water. *Jour. AWWA*, 48:1523 (Dec. 1956).
12. Black, A. P. Lime and Lime Soda Sludge Disposal. *Jour. AWWA*, 41:819 (Sep. 1949).
13. Eidsness, F. A. & Black, A. P. Carbonation of Water Softening–Plant Sludge. *Jour. AWWA*, 49:1343 (Oct. 1957).

Evaluation of Laboratory Methods for Analysis of Heavy Metals in Water

Robert C. Kroner, Dwight G. Ballinger, and Harry P. Kramer

A contribution to the Journal by Robert C. Kroner, Chemist, Analytical Reference Service; Dwight G. Ballinger, Chemist, Water Supply & Pollution Training; and Harry P. Kramer, Chief, Training Program; all from Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THIS is the second of a series of reports on the activities of the Analytical Reference Service of the Robert A. Taft Sanitary Engineering Center. Since February 1959,[1] the following agencies have joined the program: Alabama Water Improvement Commission; Flint (Mich.) Department of Public Works and Utilities; Canadian Department of National Health and Welfare, Ottawa, Ont., and Vancouver, B.C.; Tennessee Valley Authority, Chattanooga, Tenn., and Wilson Dam, Ala.; US Department of the Interior, Bureau of Reclamation, Denver Colo. The report of the first studies and a description of the purpose and scope of the program were published in an earlier issue of the JOURNAL.[1] This study on analytical methods for heavy metals in water is a natural sequel to the original studies on minerals.

Selection of Samples

The metals were chosen largely on the basis of frequency of occurrence in water, public health significance, and availability of analytical procedures, and included aluminum, copper, iron, chromium, zinc, cadmium, lead, and manganese. Metals such as beryllium, mercury, and selenium were not included because their presence in water in significant quantities is uncommon and reliable analytical methods are not available.

The sample substrate was prepared by passing good-quality distilled water through a deionizing column to remove traces of metals that might normally be present. Stock solutions of the metals were prepared from their salts and pipeted carefully into the substrate, which was then made up to final volume. The pH was reduced to approximately 2.5 with sulfuric acid. After thorough mixing, aliquots of the sample were dispensed into 1-gal polyethylene bottles preparatory to distribution. One bottle was chosen at random for analysis in the Analytical Reference Service laboratory, and the remaining bottles were shipped to all member agencies that had indicated a desire to participate in this study.

The analyses were performed in triplicate by each agency and the results were reported on a specially prepared form. Additional information requested on the form included identification of the analytical methods used for each metal and comments on each of the methods. The results of

each determination are summarized in Table 1.

Aluminum

Eleven member agencies reported on the aluminum determination, with one of them (No. 9) reporting two results. The principal method used for this determination is the aurin tricarboxylic acid (aluminon) procedure, which is recommended in *Standard Methods*.[2] This method is deceptively simple, as only two reagents are required. Iron and chromium, however, are reported to be positive interferences, but no method is given for their removal. The hematoxylin procedure, outlined in the ASTM *Manual on Industrial Water*,[3] requires eight reagents in addition to the aluminum standards. This procedure provides for removal of iron, but is complex and time consuming.

The results in general were unsatisfactory (Fig. 1), regardless of the

TABLE 1

Results of Tests on Sample Type II

Determination	Method	No. of Laboratories Reporting	Amount Added mg/l	Avg of Amounts Observed mg/l	Standard Deviation From Amount Added	
					mg/l	per cent
Iron	all methods	17	0.55	0.55	0.126	22.3
	o-phenanthroline	9		0.55		
	bypyridyl	4		0.57		
	tripyridyl	1		0.50		
	thiocyanate	3		0.57		
Copper	all methods	14	0.56	0.60	0.204	36.4
	carbamate	8		0.58		
	cuprethol	5		0.62		
	dithizone	1		0.56		
Manganese	all methods	17	0.20	0.20	0.100	50.0
	periodate	8		0.17		
	persulfate	8		0.23		
	other	1		0.23		
Aluminum	all methods	12	2.00	3.44	1.880	94.0
	aluminon	9		3.47		
	hematoxylin	1		2.52		
	other	2		3.75		
Cadmium	all methods	7	0.16	0.18*	0.061*	38.1
	dithizone	6		0.17		
	polarograph	1		0.25		
Lead	all methods	14	0.12	0.13*	0.40*	33.3
	dithizone	13		0.13		
	polarograph	1		0.18		
Chromium	diphenylcarbazide†	14	0.15	0.13	0.041	27.3
Zinc	dithizone†	11	7.47	7.73	0.979*	13.1

* One atypical result not used in calculation.
† Only method used.

method used. Among the twelve measurements reported, only one fell within 10 per cent and three within 25 per cent of the amount added. The data indicate that personnel competence is a minor factor in producing an acceptable analysis for aluminum.

After this study, a modification of the aluminon procedure was developed by Shull [4] and evaluated by the Analytical Reference Service. This new procedure was a very definite improvement and has been adopted by the AWWA subcommittee on aluminum for the eleventh edition of *Standard Methods*.

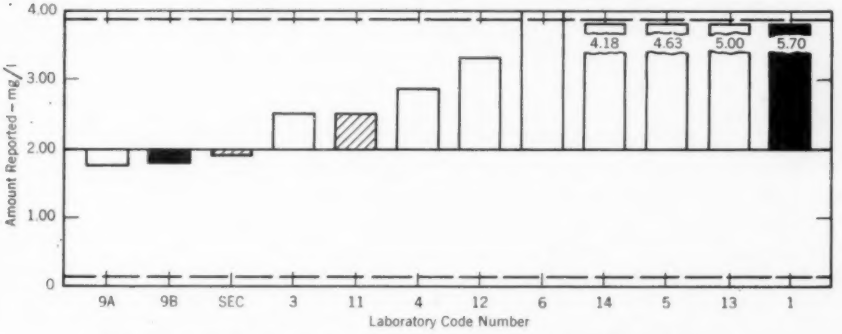


Fig. 1. Results of Three Test Methods for Determining Aluminum

The aluminum concentration of the sample was 2.0 mg/l. Dashed lines represent the standard deviation from the amount added in the reported results. Each bar represents data from a different laboratory. White bars—aluminum method, cross-hatched—hematoxylin method; solid—other.

Cadmium

Of the eight metals contained in this sample, cadmium is definitely the most difficult to measure. Only seven of the participants performed the determination and only one reported a result within 10 per cent of the true value (Fig. 2). The comments indicated that most of the laboratories encountered difficulty. In the dithizone method, loss of cadmium is often caused by acid contamination resulting from the cleaning of glassware. High values, however, may occur when excessive extraction with dithizone carries interfering metals into the final solution. Half of the participants used either nonstandard methods or modifications of the standard method.

Chromium

For the chromium determination, thirteen members reported, with No. 9 reporting two procedures (Fig. 3). Only two of the fourteen results were higher than the amount added. Half of the agencies came within 10 per cent of the true amount and three-fourths were within 20 per cent. As the amount added was only 0.15 mg/l, 20 per cent deviation represents an error of only 0.03 mg/l.

In this sample, the metal was added as hexavalent chromium in the form of potassium chromate. One fact, however, stands out: six agencies reported absence of hexavalent chromium. Apparently the metal reverted to the trivalent state under the mildly acid condition of the sample.

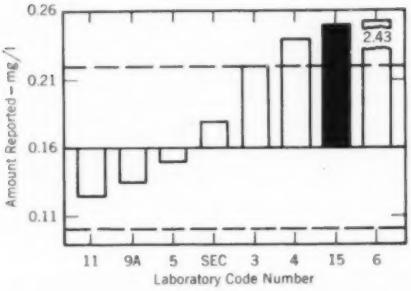


Fig. 2. Results of Two Test Methods for Determining Cadmium

The cadmium concentration of the sample was 0.16 mg/l. White bars—dithizone method; solid bars—polarographic method.

Three possible reasons for the low values reported are:

1. Loss of chromium by adsorption on the walls of the polyethylene container (This cannot be discounted until data to the contrary are available.)
2. Loss of chromium by volatilization during digestion
3. Mechanical loss resulting from transferring and filtering operations.

A fourth source of error in the determination is the presence of colloidal manganese dioxide in the filtrate after the permanganate has been reduced. To eliminate this difficulty it is suggested that the azide reduction of permanganate, which eliminates the filtering step, be substituted.[5]

Copper

For a number of reasons, the copper determination is one of the more important measurements made in the heavy-metals group. Fourteen of the cooperating agencies completed the determinations, five using the cuprethol procedure and nine using the dithiocarbamate (Fig. 4). Another reported perfect results using a dithizone method. Two did not furnish sufficient information to permit identification of the method used.

Only 40 per cent of the agencies reported values within accuracy limits of 10 per cent. From examination of the data and bar graphs, the tendency appears to be toward high results. Zinc and iron present in the sample interfere positively and are a probable cause of error. Among the five laboratories known to use the cuprethol method, the average percentage deviation from the amount added was 10.8 per cent, whereas nine laboratories using the dithiocarbamate method had an average deviation of 43.3 per cent. The provision for iron removal in the

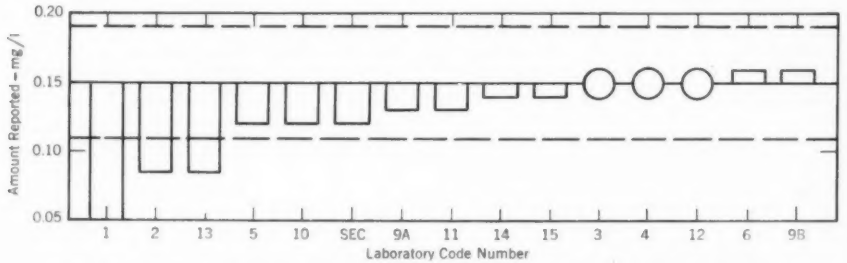


Fig. 3. Results of Diphenyl Carbazide Method for Determining Chromium

The chromium concentration of the sample was 0.15 mg/l. Circles represent perfect results.

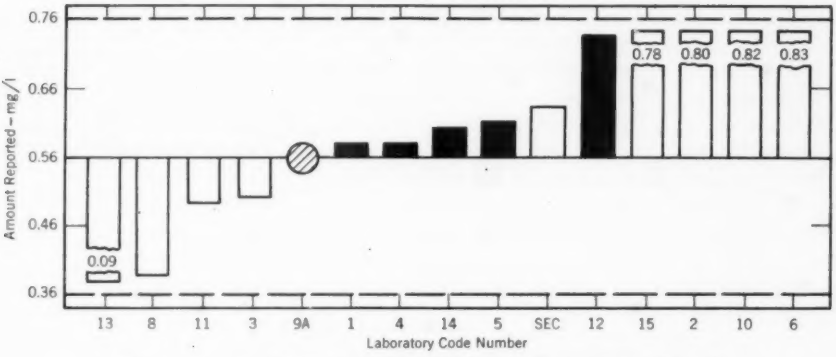


Fig. 4. Results of Three Test Methods for Determining Copper

The copper concentration of the sample was 0.56 mg/l. White bars—carbamate method; cross-hatched bars—dithizone method; solid bars—cuprethol method.

Standard Methods cuprethol procedure is apparently what accounts for the superiority of this method.

Iron

All sixteen members cooperating in this study completed the iron determination (Fig. 5), with No. 9 furnishing two values. The overall results were highly satisfactory, with fourteen of the seventeen results within 15 per cent of the true value, and eleven within 10 per cent of the amount added.

Essentially, two methods are available for the iron measurement, the thiocyanate and the *o*-phenanthroline. The *o*-phenanthroline, bipyridyl, and tripyridyl reagents are chemically related and require identical conditions of oxidation state and pH for completion of the color reaction. In addition, the *o*-phenanthroline procedure can be modified by an extraction operation which employs di-isopropyl ether to remove iron from interferers, prior to the *o*-phenanthroline addition. Both the thiocyanate and *o*-phenanthroline produced good results.

Significantly, two laboratories which employed the extraction procedure submitted high results. The possibility of trace amounts of iron in the isopropyl ether should not be overlooked.

Comparison of the procedures used does not indicate the superiority of any one method. On the basis of color stability and absence of pH control, the *o*-phenanthroline, bi-, and tripyridyl procedures would seem to be the methods of choice.

Lead

Thirteen members reported on the lead content of the sample (Fig. 6). Agency No. 15 used two procedures, the dithizone and polarographic. Normally, the dithizone procedure is the only available method for lead measurement in low concentrations. Three members (No. 3, 12, and 14) reported perfect or nearly perfect values, and nine members (better than 50 per cent) of the total reporting group, fell within 20 per cent of the amount added. It is apparent that the dithizone procedure for lead, though similar to that for cadmium, is more pre-

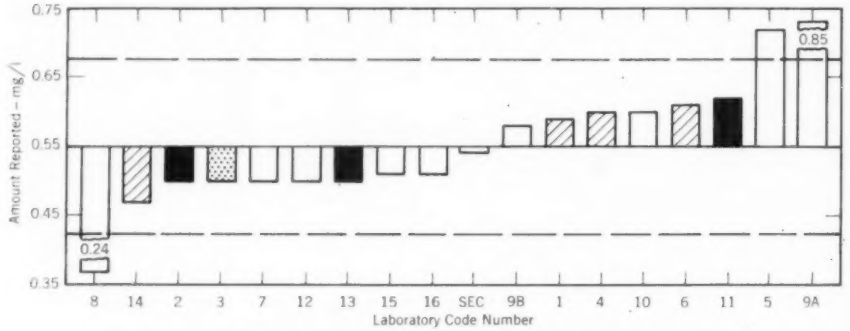


Fig. 5. Results of Four Test Methods for Determining Iron

The iron concentration of the sample was 0.55 mg/l. White bars—phenanthoroline method; cross-hatched bars—bipyridyl method; solid bars—thiocyanate method; dotted bars—tripyridyl method.

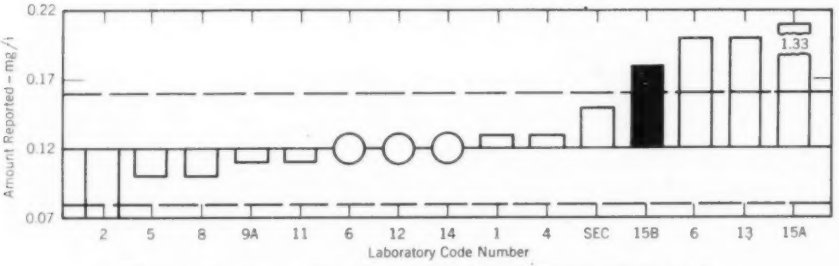


Fig. 6. Results of Two Test Methods for Determining Lead

The lead concentration of the sample was 0.12 mg/l. White bars—dithizone method; solid bars—polarographic method. Circles represent perfect results.

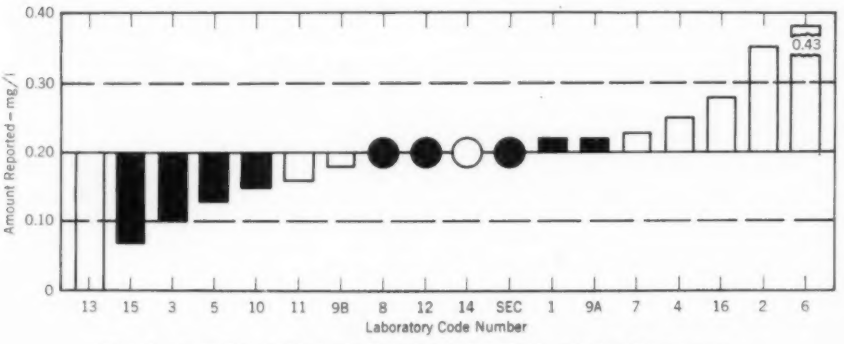


Fig. 7. Results of Two Test Methods for Determining Manganese

The manganese concentration of the sample was 0.20 mg/l. White bars—persulfate method; solid bars—periodate method. Circles represent perfect results.

cise and less subject to interferences. In view of the complexity of the method for removal of interfering materials, personnel competence is a major factor in the performance of this determination.

Manganese

Each member who received a portion of the sample reported values for the manganese determination. Agency No. 9 reported two values, making a total of seventeen manganese measurements. The results were randomly distributed between high and low values, and four members returned perfect or very nearly perfect results (Fig. 7).

The persulfate and periodate oxidation are the only methods employed for this determination. The persulfate procedure is capable of faster results but also is more subject to error, as an excess of oxidant must be maintained at all times. Furthermore, the oxidant decomposes at near-boiling temperatures and, therefore, rapid cooling of the sample is required. In the periodate method the reagent is more stable at higher temperatures, so that an excess of reagent is always maintained. Although both procedures are capable of giving good results, the periodate method appears to be less subject to error. Eight members used the periodate reagent with an average deviation of 24.6 per cent from the amount added. Seven used the persulfate oxidation and had a 52.2 per cent deviation from the amount that was added.

An error may have resulted from the fact that the special solution used in the persulfate method did not bind all of the chloride ions present in the sample.

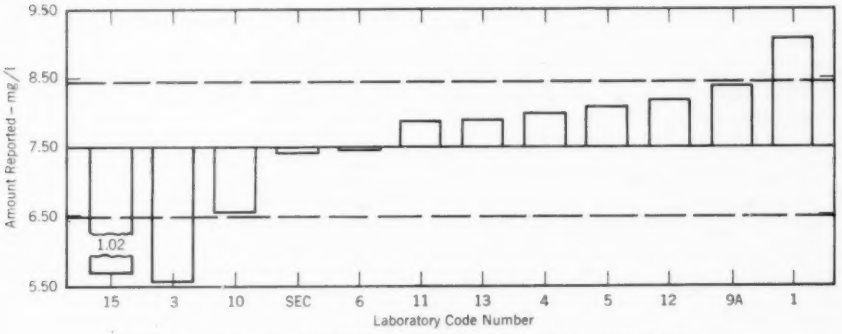


Fig. 8. Results of Dithizone Method for Determining Zinc

The zinc concentration of the sample was 7.47 mg/l.

Zinc

The zinc content of the sample was 7.47 mg/l. Owing to this relatively high concentration, gross errors in the results are not reflected in large percentage errors. Of eleven members reporting, ten came within 25 per cent of the amount of zinc added (Fig. 8). It is not possible to predict what the percentage deviation from the amount added would have been if the zinc concentration had been of the order of 1.0 mg/l. Zinc is usually determined by a mixed-color dithizone procedure. As other metals were present in much lower concentrations, deviation was

probably due to manipulative errors rather than to cross contamination.

In view of the large dilution factors used in this procedure, the ease of zinc contamination by glassware, and the complexity of separation, the overall accuracy was very high.

Interferences

Sample Type II (water, heavy metals) contained eight different metals ranging from 0.12 mg/l for lead to 7.47 mg/l for zinc. The only interferences present were the various anions added to the sample and the metals themselves. Iron interfered in both the aluminum and copper determinations. Zinc presented a hazard in the copper measurement. Chromium could interfere in the manganese determination, and every metal was a potential source of interference in the dithizone procedures for zinc, cadmium, and lead. Because no specific instructions were given for removal of interference, modification of the usual procedures was required.

Conclusion

From the raw data and bar charts two conclusions may be drawn: (1) For six of the eight metals (chromium, copper, iron, lead, manganese, and zinc) experience and personnel competence are leading factors in obtaining accurate results; and (2) the methods currently employed for the measurement of aluminum and cadmium are not satisfactory and require improvement.

Acknowledgment

The authors gratefully acknowledge the cooperation of the agencies which participated in this study.

References

1. KRAMER, H. P. & KRONER, R. C. Cooperative Studies in Laboratory Methodology. *Jour. AWWA*, 51:607 (May 1959).
2. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955).
3. Manual on Industrial Water, Technical Publication No. 148-A, Am. Soc. for Testing Materials, Philadelphia, Pa. (1954).
4. SHULL, K. C. (*unpublished data*).
5. LIEBER, MAXIM. Permanganate-Azide Test for Total Chromium in Water. *Jour. AWWA*, 48:295 (Mar. 1956).

Chlorine Supply and Use in Water and Sewage Treatment Plants

Joint Committee Report

A report of Joint Committee 7330 J—Chlorine Supply, submitted by Warren J. Scott (Chairman), Director, San. Eng. Div., Connecticut State Dept. of Health, Hartford, Conn. The other Conference of State Sanitary Engineers representative was B. A. Poole. AWWA representatives were R. J. Faust and H. E. Jordan; FSIWA representatives were H. A. Faber and W. E. Gerdel; and the USPHS representative was L. F. Warrick.

IN August 1953, the Joint Committee on Chlorine Supply submitted its initial report dealing with the supply, inventories, and use of chlorine in water and sewage treatment plants.[1] Committee recommendations on chlorine inventories presented in the report were based on: (1) delivery time from distributor to user, (2) average and maximum rates of consumption, and (3) interruption of chlorine delivery to users. Three stages of inventory were defined:

1. *Critical inventory,* a reserve of containers of chlorine not in use, equal to the number normally connected and in service

2. *Working inventory,* equal to the critical inventory, plus a reserve equivalent to the amount of chlorine consumed during a period equal to the length of time required for delivery, and a 15-day emergency supply

3. *Maximum inventory,* equivalent to a 60-day supply at normal rates of use.

Committee recommendations on chlorine inventories, presented in the 1953 report, are shown, in part, in Table 1.

Followup Study

In May 1958, the committee planned a followup survey of representative water and sewage treatment plants in the continental United States. A total of 191 cities were selected, which represented the range of urban population sizes in each of five geographic sections of the country. Approximately the same number of cities in each population range were selected for each section. From each city, water and sewage treatment plants serving the same communities were chosen. Of the total number selected, data were received from 151 water plants and 51 sewage treatment plants (Table 2); these data have been used to develop the compilations and analyses of this report. The small number of returns from the sewage treatment plants is attributed to the relatively small percentage of sewage plants using chlorine.

Estimated 1959 data indicate that 151 water treatment plants reporting serve 17.4 per cent of the total population of the United States served by water treatment plants, and 20.9 per

cent of the population served by plants using liquid chlorine for disinfection. The survey included 3.5 per cent of the number of plants using liquid chlorine for disinfection in 1948.[2]

The 51 sewage treatment plants reporting serve 10.3 per cent of the total population served by sewage plants, and 28.5 per cent of the population served by plants chlorinating with liquid chlorine. The reporting plants represent 3.2 per cent of the number of plants using liquid chlorine.[3, 4]

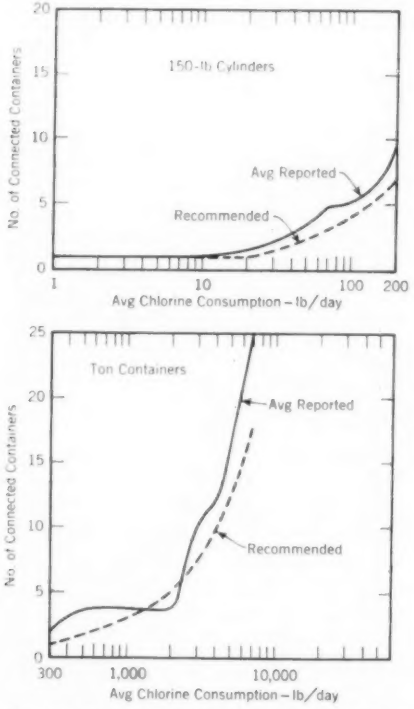


Fig. 1. Reported and Recommended Number of Connected Units for Various Rates of Chlorine Consumption at Water Treatment Plants

The average number of connected units reported exceeded committee recommendations in all but a few instances.

The objectives of the followup study were to compare inventories and stocks with those recommended in the 1953 report, and to determine what stocks of chlorine are being kept and how they are being used. In this report, six points of the eleven discussed in the initial report will be reconsidered:

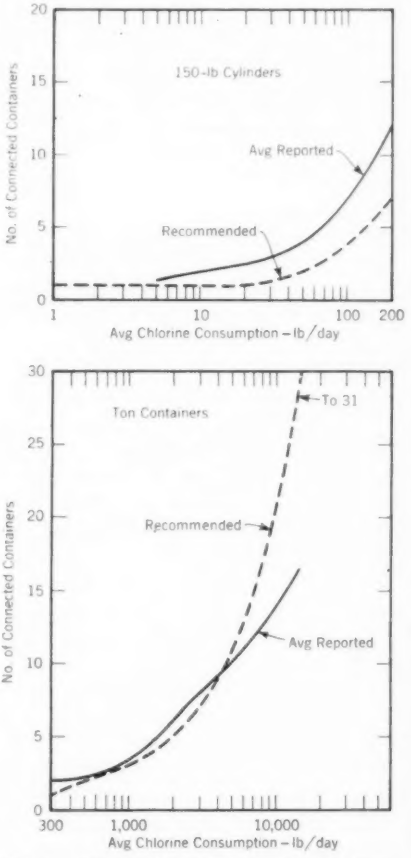


Fig. 2. Reported and Recommended Number of Connected Units for Various Rates of Chlorine Consumption at Sewage Treatment Plants

For the most part, the average number of connected units reported exceeded committee recommendations.

TABLE 1

Recommended Chlorine Inventories in Relation To Chlorine Consumption

Avg Daily Chlorine Consumption *lb*	Critical Inventory	Working Inventory*	Maximum Inventory
	No. of 150-lb Cylinders		
2	1	1	2
5	1	1	3
10	1	3	4
20	1	4–5	8
50	2–3	8–12	20
100	3–5	16–24	40
200	6–8	30–47	80
	No. of Ton Containers		
300	1	4–6	9
500	2	8–10	15
1,000	2–4	12–18	30
2,000	4–6	22–35	60
5,000	11–13	54–82	138
10,000	16–18	85–137	

* Where ranges are shown, the smaller of the two numbers represents the working inventory when deliveries take 2 days. The larger number represents the working inventory when deliveries take 15 days.

1. Use of chlorine cylinders and ton containers
2. Chlorine inventories at water and sewage treatment plants
3. Stationary bulk storage of liquid chlorine at treatment plants
4. Transportation of liquid chlorine from supplier to user
5. Standby (maximum) chlorinator capacity
6. Provisions for emergency supplies.

Also to be discussed is one additional point concerning delays in chlorine deliveries during the past 5 years.

Cylinders and Ton Containers

Table 3 presents data on the recommended size and use of chlorine containers at water and sewage treatment plants, and on the number of plants utilizing the recommended containers. Figures 1 and 2 compare the averages of the reported number of cylinders connected for service with the number recommended by the committee. When the average number of connected units for the average daily rate of use is used as a basis, both water and sewage plants exceed committee recommendations in all but a few instances.

Table 3 shows that 128 of 148 water treatment plants use containers sized according to committee recommendations, which were based on the average and maximum rates of chlorine use. Only three of the plants having maximum rates of chlorine consumption greater than 300 lb/day were using 150-lb cylinders in place of the 1-ton units recommended. Nine plants consuming chlorine at a rate of less than 300 lb/day used 1-ton units, rather than the recommended cylinders. When the 9 plants using oversized units are included, 120 used a number of connected units equal to or greater than the number recommended for their range of chlorine consumption.

Table 3 also shows that 44 of 50 sewage treatment plants utilize 150-lb or 1-ton containers in accordance with committee recommendations. All six plants not corresponding to committee

TABLE 2

Location in the United States and Number of Plants Returning Data

Location	No. of Water Plants	No. of Sewage Plants
Northeast	32	13
Southeast	19	7
North Central	37	7
Southwest	21	4
West	42	20
Total	151	51

recommendations utilized 1-ton containers in place of cylinders, which were considered the proper units for plants having maximum consumption rates of less than 200 lb/day of chlorine. With these six plants included, 40 of the total of 50 plants reporting indicated the use of an equal or greater number of connected containers than had been recommended by the committee.

Inventories

As mentioned before, the recommendations of the 1953 report for critical and working inventories are shown in Table 1.

Figures 3 and 4 compare the average working inventories reported with the working inventories recommended for each given rate of chlorine consumption. It will be noted that the working inventories reported for both water and sewage treatment plants are slightly less than those recommended in the 1953 report. Table 4 shows a comparison of actual working inventories at water plants, with working inventories recommended for various rates of chlorine consumption. Table

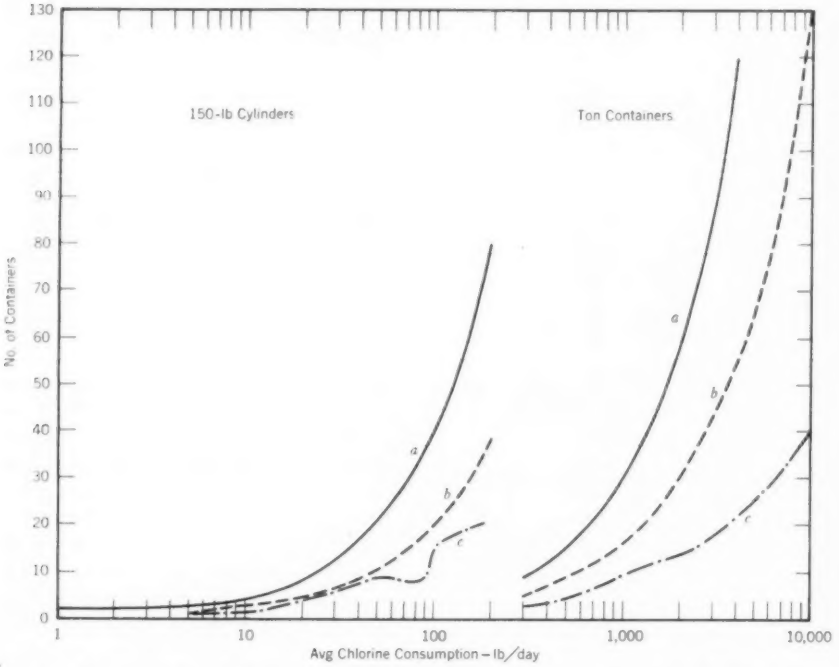


Fig. 3. Comparison of Recommended Working Inventory, Recommended Maximum Inventory, and Reported Average Working Inventory for Various Rates of Chlorine Consumption at Water Treatment Plants

Curves a, b, *and* c *represent recommended maximum inventories, recommended working inventories, and reported average working inventories, respectively.*

5 shows the number of water plants in each average consumption range that have working inventories equal to or greater than those recommended. The comparison indicates that approximately one-third of the water plants have working inventories equal to or greater than those recommended and had inventories equal to or greater than those recommended. This value, however, unlike the one for water plant inventories, is not generally representative for all ranges of average daily use. Those plants using the most chlorine, more than 300 lb/day, generally had much smaller inventories than were recommended. As over one-third of the sewage plants reporting were in this group, the inference is that total inventories at the sewage treatment plants, as a whole, conformed to committee recommendations in about the same way as total inventories at the water treatment

TABLE 3

Recommended and Actual Use of Chlorine Containers in Water and Sewage Treatment Plants

Daily Chlorine Consumption lb		No. of Plants in Consumption Range	Connected Containers			
Avg	Max.		Number Recommended	No. of Plants With Recommended Number or More	Size Recommended	No. of Plants Using Recommended Size
Water Treatment Plants						
100	100	58	1–6	46	cylinder	51
100	200	22	5–8	12	cylinder	14
200	200	2	5–10	1	cylinder	0
200	300	13	1	13	ton	13
300+		53	1+	33	ton	50
Total		148		105		128
Sewage Treatment Plants						
25	50	19	1	19	cylinder	17
50	100	2	2	0	cylinder	0
100	100	1	3–6	1	cylinder	1
100	200	3	5–8	1	cylinder	1
200	200	2	5–10	2	cylinder	2
200	300	6	1	6	ton	6
300+		17	>1	11	ton	17
Total		50		40*		44

* Includes six plants using ton containers in place of recommended 150-lb cylinders.

that, when based on average rates of consumption, this value generally holds true for the full range of users. On the same basis, working inventories ranged from a 14-day to a 30-day supply, averaging about 26 days.

Table 5 further indicates that one-half of the sewage treatment plants

plants. Based on average daily consumption, working inventories at sewage plants ranged from 10 to 31 days, with a median of about 22 days.

Stationary Bulk Storage

Only one of the water and sewage plants utilized stationary bulk storage of liquid chlorine. On the basis of average daily consumption rates and size of chlorine container used, and the type of shipping used by 157 of the water plants. It is of interest that the great percentage of deliveries are made by truck—that is, 127 of 157 plants, or 81 per cent, are supplied by truck—and that the suppliers of 97 of the plants are located less than 100 mi from the plant. Only three of the plants used rail tank cars.

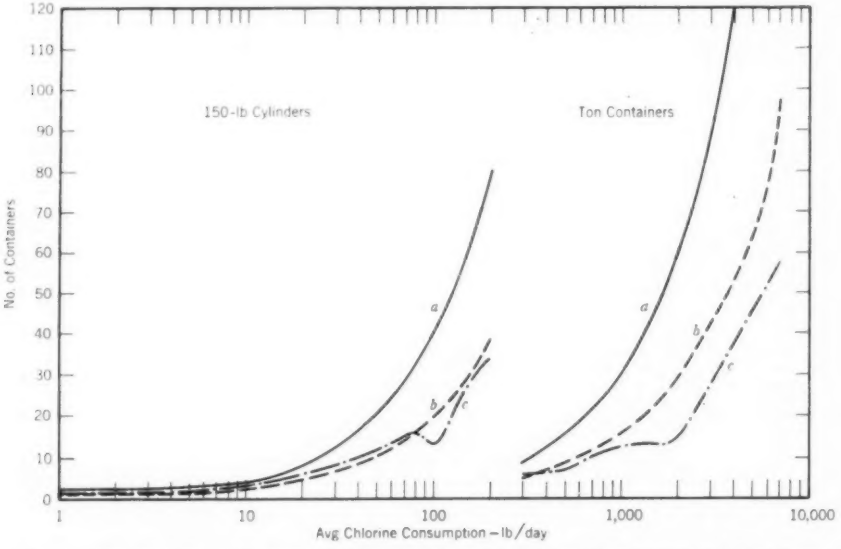


Fig. 4. Comparison of Recommended Working Inventory, Recommended Maximum Inventory, and Reported Average Working Inventory for Various Rates of Chlorine Consumption at Sewage Treatment Plants

Curves a, b, *and* c *represent recommended maximum inventories, recommended working inventories, and reported average working inventories, respectively.*

the number of connected ton containers required to meet recommendations for these consumptions, it appears that other large plants might evaluate the feasibility of bulk storage.

Shipping

Table 6 compares the distance of plants from the chlorine supplier, the

Table 6 also shows that of 53 sewage treatment plants, 36, or 68 per cent, were less than 100 mi from their suppliers. A total of 44 plants, or 83 per cent, used truck delivery. Again, only three plants used railroad tank cars.

It is significant that most plants are relatively close to their suppliers and

do not depend on rail deliveries. In an emergency, a reserve supply for these plants would be limited only by the availability of truck transportation, usable highways from suppliers to plants, and the reserve stock at the suppliers.

Capacity and Demand

Figure 5 compares the average daily consumption, maximum daily consumption, and maximum chlorination capacity for various rates of chlorine consumption. The slopes of these graphic representations indicate a fairly constant relationship of demand to treatment capacity. The ratios of maximum daily consumption to maximum chlorinator capacity ranged from

TABLE 4

Comparison of the Number of Connected Units and the Working Inventories Recommended for Water Treatment Plants With Averages of Those Reported

Avg Daily Chlorine Consumption *lb*	Connected Units		Working Inventory	
	No. Recommended	Avg No. Reported	No. of Units Recommended	Avg No. of Units Reported
	150-lb Cylinders			
2.5	1	1	1	1
10	1	1.6	3	3.6
20	1	2.2	4.5	6.9
50	2.5	7.3	10	10.2
100	4	12.2	20	34.7
200	7	20	38.5	51.4
	Ton Containers			
300	1	2	5	5.7
500	2	3.7	9	7.4
1,000	3	3.9	15	13.7
2,000	5	3.8	28.5	13.7
3,000	8	10.5	43.5	37
5,000	12.5	13.8	71.3	36.4
7,000	15	25	95	58

TABLE 5

Compliance of Water and Sewage Treatment Plants With Recommendations for Working Inventories

Avg Daily Chlorine Consumption *lb*	No. of Units* in Recommended Working Inventory	Size of Working Inventory	
		Smaller Than Recommended	Equal to or Larger Than Recommended
		No. of Water Treatment Plants	
0.5	1	0	0
2	1	0	0
5	1	3	2
10	2	7	9
20	4–5	16	12
50	8–12	25	9
100	16–24	15	5
200	30–47	9	3
300	4–6	5	4
500	8–10	3	0
1,000	12–18	2	1
2,000	22–35	6	0
>2,000		6	3
Total		97	48
		No. of Sewage Treatment Plants	
0.5	1		
2	1		
5	1	0	3
10	2	1	3
20	4–5	3	5
50	8–12	3	2
100	16–24	4	2
200	30–47	0	4
300	4–6	1	0
500	8–10	3	3
1,000	12–18	3	0
2,000	22–35	0	0
>2,000		5	1
Total		23	23

* For chlorine consumption rates varying from 0.5 lb/day to 200 lb/day, 150-lb cylinders are used; for greater rates of consumption, ton containers are used. Where ranges in the number of units are shown, the smaller of the two numbers represents the working inventory when deliveries take 2 days; the larger number represents the working inventory when deliveries take 15 days.

1:2.1 to 1:2.9. If it is assumed that reserve supplies of chlorine are available, then most plants have sufficient capacity to handle foreseeable emergency demands.

Emergency Supplies

Only 44 of 148 water treatment plants reported that arrangements had been made to obtain emergency supplies of chlorine. Most of these plants

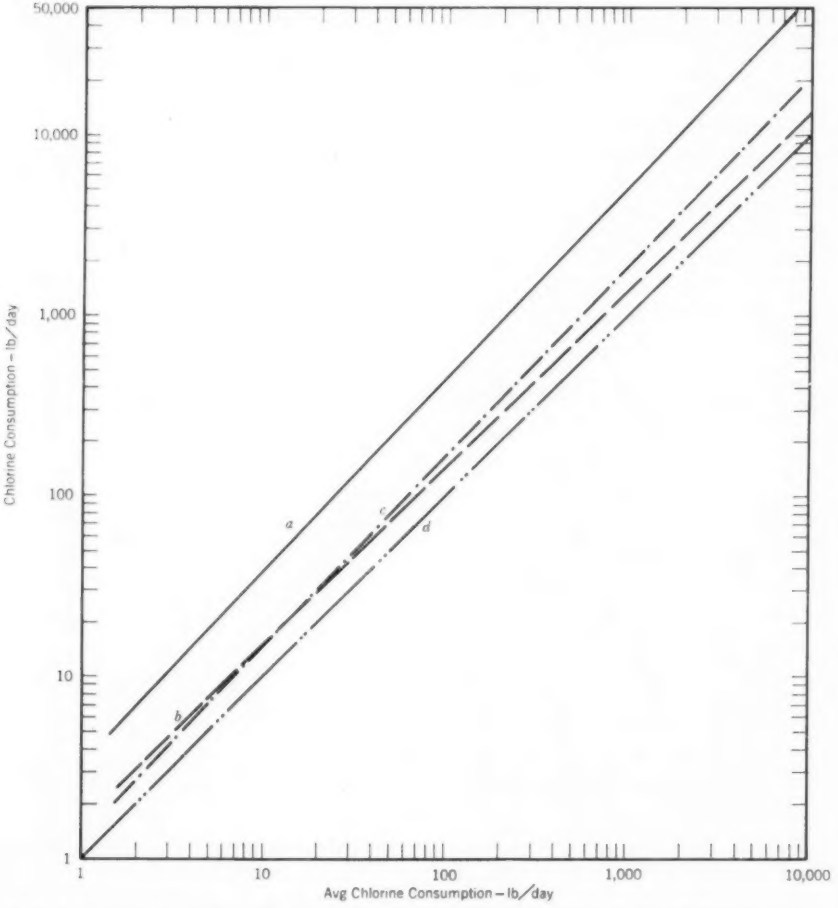


Fig. 5. Comparison of Average Daily Consumption, Maximum Daily Consumption, and Maximum Chlorination Capacity at Water and Sewage Treatment Plants

Curve a *represents the total chlorinator capacity at water treatment plants. Curves* b *and* c *represent the maximum daily chlorine consumption at sewage and water treatment plants, respectively. Curve* d, *a 45-deg line, represents the average daily chlorine consumption.*

had agreements with alternate suppliers or nearby industrial firms. Only three plants reported that in emergencies they planned to use the chlorine supplies located at local swimming pools or sewage treatment plants.

Sewage treatment plants were not requested to return information concerning emergency supplies.

Delays in Delivery

Perhaps the reason that so few plants have made specific plans for emergency chlorine supplies is that they have come to rely on dependable service from suppliers. Only eight of the water treatment plants and five of the sewage treatment plants had experienced delays or interruptions in

TABLE 6

Shipping Distance, Mode of Chlorine Transportation, and Type of Chlorine Container for Water and Sewage Treatment Plants

Distance From Supplier mi	Mode of Chlorine Transportation						
	150-lb Cylinders			Ton Containers			Tank Car
	Truck	Rail	Truck & Rail	Truck	Rail	Truck & Rail	
	No. of Water Treatment Plants						
<50	26	0	0	20	1	0	1
100	26	0	1	17	4	0	1
200	15	1	0	13	3	0	0
300	2	0	1	0	1	1	0
400	2	0	0	1	3	0	0
500	3	1	0	2	1	0	0
600	0	0	0	2	1	0	0
700	0	0	0	0	1	0	1
800	0	0	0	0	1	0	0
900	0	0	0	0	2	0	0
1,000+	0	0	0	0	2	0	0
*Totals**	74	2	2	55	20	1	3
	No. of Sewage Treatment Plants						
<50	14	0	0	18	0	0	1
100	2	0	0	1	0	0	0
200	3	1	0	2	1	0	0
300	1	1	0	2	0	0	0
400	0	0	0	0	1	0	0
500	1	0	0	0	0	0	1
600	0	0	0	0	0	1	1
700+	0	0	0	0	1	0	0
*Totals**	21	2	0	23	3	1	3

* The overall totals do not equal the number of plants reporting, as shown in Table 2, because several plants use both cylinders and ton containers.

deliveries since 1953. These plants were not confined to any particular part of the country, and the reasons for the delays varied. Strikes were the most frequent cause reported. Two plants reported that their delivery problems were solved when they began using ton containers instead of 150-lb cylinders.

Summary

The number of plants surveyed is too small for a detailed study of relationships between plant operations and plant size and locations. Some general relationships, however, are clearly shown.

1. Although working inventories are kept at fairly high levels, they are below recommended levels at two-thirds of the water plants and at one-half of the sewage treatment plants. Working inventories range from a 14- to 30-day supply at water plants, and from a 10- to 31-day supply at sewage plants.

2. Only one plant reported having stationary bulk storage facilities. Other large plants might also study the feasibility of bulk storage.

3. Most plants have chlorinator capacity ranging from two to three times maximum demand.

4. Relatively few water plants have arranged for emergency supplies.

5. Only a few plants have experienced delays in delivery during the past 5 years.

Conclusions

1. Working inventories should be increased at most water and sewage treatment plants. The Joint Committee on Chlorine Supply recommends that water treatment plants should be able to operate, with the use of available inventories, for a period of at least a month.

2. The committee has received no criticisms of its earlier report on recommendations concerning inventories. From the results of its present study, the committee believes that the earlier recommendations merit favorable consideration by the management of water and sewage treatment plants. It is urged that management evaluate its chlorine supplies and operating procedures to determine if they are adequate for emergencies.

3. Undetermined by this survey is the supply of chlorine containers available for the water and sewage plants through supply channels. As availability of containers would control the maximum amount of chlorine available to water and sewage treatment plants at any given time, such a survey would afford a worthwhile supplement to this report.

References

1. JOINT COMMITTEE REPORT. Recommended Procedures in the Use of Chlorine at Water and Sewage Plants. *Jour. AWWA*, 45:1060 (Oct. 1953); and *Sew. & Ind. Wastes*, **25**:1235 (1953).
2. THOMAN, J. R. Statistical Summary of Water Supply and Treatment Practices in the United States. Publication No. 301, USPHS, Washington, D.C. (1953).
3. THOMAN, J. R. & JENKINS, K. H. Statistical Summary of Sewage Works in the United States. Publication No. 609, USPHS, Washington, D.C. (1958).
4. THOMAN, J. R. & JENKINS, K. H. Statistical Summary of Sewage Chlorination Practice in the United States. *Sew. & Ind. Wastes*, 30:1461 (1958).

Alum Supply and Use in Water Treatment Plants

Joint Committee Report

A report of Joint Committee 7330 J—Chlorine Supply, submitted by Warren J. Scott (Chairman), Director, San. Eng. Div., Connecticut State Dept. of Health, Hartford, Conn. The other Conference of State Sanitary Engineers representative was B. A. Poole. AWWA representatives were R. J. Faust and H. E. Jordan; FSIWA representatives were H. A. Faber and W. E. Gerdel; and the USPHS representative was L. F. Warrick.

IN the course of its 1958 survey of chlorine supply and use in water and sewage plants, the Joint Committee on Chlorine Supply considered it desirable to gather information on alum as well, because that chemical is of comparable importance to chlorine in water treatment. The report on chlorine, to which reference should be made for a description of the survey sample, appears in the preceding pages of this issue.[1]

In the alum portion of the survey, water treatment plant management was asked:

1. Is alum used for treatment?
2. Is alum necessary for emergency treatment?
3. What is the minimum stock of alum maintained?
4. What is the average and maximum daily consumption?
5. What length of time is required for delivery from the supplier?

The answers received showed that alum is used for treatment at 112 of the 153 water treatment plants reporting, and that 72 of these considered alum a necessity for emergency operation. There was an attempt to correlate the data with the location and size of the plants (population served). The only significant conclusion made from these correlations (Table 1) is that a large number of plants using alum and reporting it necessary for operation are located in the twelve North Central states. A total of 32 plants of the 112 using alum are in these states; 25 of these plants considered alum a necessity.

Daily Consumption

Table 1 shows the alum consumption at water plants, according to their location and size. The wide and irregular variations in consumption indicate that no significant relationships may be inferred from these data. These differences are undoubtedly the result of well known variations in water quality due to the location of water and the season of the year. Such variations, in a relatively small sample of water plants from different parts of the country, do not permit comparison.

Minimum Stocks

Based on the average daily consumption reported, minimum stocks

TABLE 1

Consumption and Minimum Stocks of Alum at Water Treatment Plants in the United States

Plant Location and Population Served *1,000's*	Avg Daily Consumption *1,000 lb*		Max. Daily Consumption *1,000 lb*		Min. Stock—*1,000 lb*	
	Range	Median	Range	Median	Range	Median
Northeast						
100	0.167–4.5	2.7	0.472–13.5	4.1	20–740	60
50–100	1.2–3.5	3	1.9–7	6.5	30–80	50
10–50	0.44–5.7	0.55	0.9–12	1	6–60	20
Southeast						
100	1.2–16	6	2.2–42	15	5–160	25
50–100	5–5.5	5.2	9–11	10	35–80	55
10–50	0.3–1.5	0.5	0.4–1.7	1	2–28	10
10	0.03–0.1	0.065	0.15–1	0.575	3–10	6.5
North Central						
100	4–42.2	7.2	12–144	33.5	250–1,250	300
50–100	1.2–2.7	1.3	1.6–8	1.8	1.2–40	20
10–50	0.085–2.6	0.6	0.2–4	1.5	1–40	11
10	0.06–0.4	0.35	0.11–1.1	0.6	1–10	4
Southwest						
50–100	0.8–2	2	2.5–8	3	20–50	28
10–50	0.4–0.55	0.5	0.65–0.8	0.75	1.5–80	2.5
10	0.087–0.4	0.245	0.105–1.2	0.65	2–5	3.5
West						
10–50	10–2.14	1.96	1.6–11.34	3.7	11–120	20
10	0.075–0.18	0.13	0.1–0.25	0.175	2–5	3.5

ranged from a 5-day to a 30-day operating inventory, with a median of about 22 days. There was no connection noted between the size of the operating inventory and the plants that require alum in emergencies. The conclusion reached, for these plants at least, is that in case of emergency the supply of alum may be more critical than the supply of chlorine.

Summary

1. About one-half the water treatment plants reporting considered alum an absolute necessity for treatment.

2. The minimum stock of alum maintained at water treatment plants ranged from a 5-day to a 30-day supply, which is generally smaller than chlorine stocks at the same plants.

Conclusion

Large alum inventories should be maintained at water plants that require alum for adequate treatment.

Reference

1. JOINT COMMITTEE REPORT. Chlorine Supply and Use in Water and Sewage Treatment Plants. *Jour. AWWA*, 51:125 (*this issue*).

Study of Short Filter Runs With Lake Michigan Water

Merrill B. Gamet and John M. Rademacher

A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Merrill B. Gamet, Cons. to USPHS and Prof., Dept. of Civ. Eng., Northwestern Technological Inst., Evanston, Ill., and John M. Rademacher, San. Engr., Region V, USPHS, Chicago, Ill.

THE increase in water consumption during recent years has emphasized the necessity for water utility personnel and engineers to produce a high-quality product economically and in sufficient quantities. This is particularly true during peak-demand periods, which may often coincide with unfavorable operating conditions caused by adverse water quality. The treatment methods used to cope with these conditions are not normally successful and inevitably result in short filter runs. The short filter run is important primarily because it results in loss of revenue to the water utility. Although conditions vary, the efficiency of filter runs may be evaluated on the basis of an economic breakpoint, which is usually taken to be 20 hr. Filter runs shorter than 20 hr account for the greatest amounts of waste.

Short filter runs create expensive problems. Loss in plant capacity and excessive wash water usage are attributable directly to this problem. In addition, poor raw-water quality, which, in turn, usually requires higher chemical dosages, generally occurs during periods of short filter runs. If such periods are prolonged, the water treatment plant so afflicted is faced with a sizable financial loss, possible costly plant expansion, and, of more importance, a reduction in service adequacy.

Study Program

The problem of short filter runs is confronting a great many water utilities, and, in 1957, USPHS initiated a cooperative program to investigate the situation as experienced by representative water treatment plants using Lake Michigan as a source of supply.

The state boards of health of the Lake Michigan border states were informed of the desire to select a project sponsor. The Lake Michigan West Shore Water Producers Association agreed to serve in this capacity. Formal requests for project support were made to the states of Wisconsin, Illinois, Indiana, and Michigan. Support was received and the boards of health then requested USPHS to provide financial aid and personnel to implement the project. Cooperation was also received from the Robert A. Taft Sanitary Engineering Center, the Great Lakes Research Institute at the University of Michigan, the Northwestern Technological Institute, and the Michigan West Shore Water Works Operators Association. The study is a regional one, as can be

seen from the several organizations and agencies represented.

A research committee was appointed by the sponsor to cooperate with the Chicago regional office of USPHS. This group initiated plans and established the following objectives for the project:

1. To determine the magnitude of the short filter run problem
2. To identify the specific adverse effects of short filter runs
3. To identify the water quality and other conditions which contribute to poor sedimentation and short runs
4. To investigate the methods by which the various treatment plants have attempted to solve the problem
5. To evaluate the additional cost of treatment and the losses of revenue
6. To develop new treatment methods or improvements on existing methods under adverse water quality conditions and thereby provide a more satisfactory operating cycle, particularly during peak-demand periods.

Field Procedure

Twelve filtration plants were selected to participate in the field study. The selection was based on type of treatment facilities, adequacy of laboratory space and equipment, and whether enough qualified personnel were available to carry out the burden of additional duties. It was necessary that normal plant operations not be overtaxed and that plant personnel be enthusiastic and willing to cooperate in the program.

The twelve plants actively engaged in the field study are Green Bay, Sheboygan, and Milwaukee, Wis.; Waukegan, Evanston, and Chicago, Ill.; Gary-Hobart and Michigan City, Ind.; and Benton Harbor, Holland, Grand Rapids, and Muskegon, Mich. Their geographical locations are shown in Fig. 1.

The study was planned to include investigations of all of the known variables in short filter runs, from the raw water to the delivered product. These variables include: weather and lake conditions; treatment facilities as installed in the various plants; physical, chemical, and biological characteristics of the raw and settled water; amounts and kinds of chemicals used in treatment, plant performance under varying operating conditions, together with the production costs incurred.

Fig. 1. Cities Participating in Lake Michigan Filter Run Study

All of the cities that participated are shown above.

The field study began on Jan. 1, 1958, and continued through 1959. Three special data forms were designed for tabulation of the project data. Weather conditions, wind direction, and lake surface current direction are coded for ease of tabulation. Data shown in the forms include:

1. Daily maximum and minimum temperatures of both raw and finished waters; maximum and minimum air temperatures; turbidity of raw, settled, and finished waters; pH of raw and finished waters; raw-water alkalinity; chlorine demand; chlorine residual in raw and settled waters; chemical dosages; volume treated; total wash water used; length of average run; and remarks (Form 1)

2. Flow rate, length of run, head loss, volume filtered (gallons per foot of head loss per square foot of filter surface), volume of backwash, volume of surface wash, percentage wash water used, and length of backwash period for each filter run (Form 2).

3. Daily organism counts for raw and settled water and percentage removal (Form 3).

All of the data received are transferred to punched cards to simplify storage, sorting, and tabulating for correlation studies and computing with high-speed digital computers.

Correlation of data between plants was facilitated by the use of certain operational controls. For example, throughout the field study, each plant operates one filter as a test unit at a constant rate of 2 gpm/sq ft and another filter at demand rate. The constant-rate filter is backwashed at essentially the same net loss of head of 7.0 ft for each run. These data are recorded on Form 2, as noted above.

Further aid in data correlation is obtained by use of a quantity called the "filter performance index," or the amount of water filtered in each run per foot of head loss per square foot of filter surface area. This index is a convenient means of comparing and analyzing filter operation between the several plants because it reduces filter area and head loss to a unit value. For example, a filter that operates at a rate of 2.0 gpm/sq ft and is washed at a net head loss of 7.0 ft will have a filter performance index of 171, if the filter operates for 10 hr during a given run.

All plants were requested to perform most of their laboratory control methods and techniques in accordance with AWWA standards, although some deviations from these standards were specified. For example, methyl purple was used for alkalinity determinations because it has a sharper endpoint, the modified Baylis turbidimeter for turbidity measurements because of its low initial cost and its accuracy to one-tenth of a unit, and the direct clump count for plankton determinations.

Plankton Counts

Plankton in settled water have long been suspected of being the major cause of short filter runs. Much attention has therefore been devoted to the counting technique, competency of the counters, and statistical analyses of the results.

The counting method adopted for use in this project was the direct clump count. This method was selected because of its relative simplicity for plant personnel and the limited time available for making the counts at the plants. The method normally involves the counting of two long strips, equivalent to about 100 fields, along the length of a Sedgwick-Rafter counting cell. On the assumption that the strips are representative of the entire cell, the count is reported in clumps per milliliter. It is important to determine the relative significance of the different diatoms with respect to filter

clogging tendencies. To express this tendency, multiplication factors have been determined which permit conversion of clump counts to volumetric equivalents.[1] All clump counts are being so converted for analysis.

Reference samples were collected at Chicago in February, May, July, and August 1958, and portions of each sample were distributed to each plant for counting to determine the uniformity of results of the individual counters. An analysis of the results of the first sample indicated that additional training of personnel in organism identification would be required. Consequently, a series of plankton-counting clinics was conducted. Considerable improvement resulted from each one.

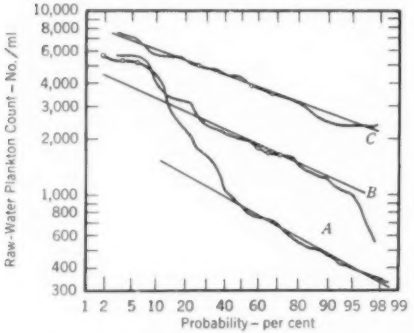


Fig. 2. Analysis of Plankton Reference Samples

Irregular Curves A, B, *and* C *are plots of actual counts made by participating plant and Taft Center personnel on reference samples for Feb. 28, May 28, and Aug. 28, 1958, respectively. Straight lines indicate trends in sample distribution error. Deviations from straight lines indicate counting error.*

Statistical analyses were made of each of the reference samples. The observations were arrayed in order of magnitude and plotted on logarithmic graph paper. It was noted that the points fitted a geometrically normal distribution. The positions of plots of the arrayed observations are determined by the formula,

$$F = \frac{100\,i}{n+1}$$

in which F is the probability in per cent, n is the number of observations, and i is the position of any value in the array $(1,2,3 \ldots n)$.

Figure 2 gives a comparison of the analysis of several representative reference samples. Plotted points which are circled represent results obtained by Robert A. Taft Sanitary Engineering Center personnel. These are assumed to be within desired limits of accuracy and are used as a basis of comparison for all other observations.

Curve *A*, for Feb. 28, 1958, shows poor agreement between plankton counts as determined by the various observers. In addition, this curve shows that all counters obtained lower counts than Taft Center personnel, thus indicating that observation of many organisms was incomplete.

Curve *B*, for May 28, 1958, indicates a marked improvement of counting ability. It also indicates some agreement between observations. Counters made observations that were both above and below the expected values.

Curve *C*, for Aug. 28, 1958, shows that observations reached a reasonably good, geometrically normal distribution with the counts made by Taft Center personnel falling around the 50 per cent point. This is the pattern that would be expected for statistical phenomena of this nature.

It is important to note that those counts made at the Taft Center fall on

essentially straight lines in all curves. This would indicate error only in sample distribution. It can then be assumed that Curve *C* shows the standard deviation of the sample, and that variations of observations from this line indicate errors in counting.

Filter Run Summary

A study was made to determine the prevalence of short filter runs and to obtain comparative data on the performance of the test filters. These filters were operated at a nearly constant rate of 2 gpm/sq ft at the twelve plants from Jan. 1 to Sep. 30, 1958. Tabulations were made of the total number of runs and the average length of runs for the 9-month period (Table 1). Table 2 shows percentages of the total number of runs less than 20, 15, 10, and 5 hr at each plant. Percentages of runs shorter than 20 hr at different increments of plant capacity in operation at each plant are shown in Table 3. It will be observed that the number of test filter runs at all twelve plants totaled 2,542, from a minimum of 108 to a maximum of 368. The average length of filter runs for all plants for the test filters was 32.7 hr, ranging from a minimum of 16 hr to a maximum of 61 hr.

There are several possible reasons for the variations in average length of filter runs. Filter performance may be affected by sand size. In order to compare filter operation when varying sizes of sand are used, sand samples were collected from the test filters in each plant. These samples were collected from the top 6-in. of sand in the filters. The average Hazen 10 per cent effective size, Baylis effective size, and uniformity coefficient were determined for each sample collected. The Baylis effective sand sizes range from a minimum of 0.56 mm to a maximum of 0.67 mm. One plant used an anthracite medium with an effective size of 0.78 mm.

TABLE 1

Test Filter Summary for Participating Plants, Jan. 1–Sep. 30, 1958

Plant No.	Plant Design Capacity *mgd*	Total No. of Runs	Avg Length of Runs *hr*
1	20	112	53
2	18	296	16
3	200	211	31
4	10	322	16
5	48	199	32
6	320	368	18
7	36	227	29
8	12	108	61
9	12	122	52
10	14	152	22
11	44	185	34
12	16	206	29
Totals	750	2,542	*Avg* 32.7

TABLE 2

Summary of Short Filter Runs on Test Filters

Plant No.	Percentage of Total Runs			
	< 20 hr	< 15 hr	< 10 hr	< 5 hr
1	0	0	0	0
2	74	57	35	12
3	33	14	2	0
4	50	24	6	0
5	32	21	9	2
6	69	61	33	4
7	33	19	9	2
8	1	0	0	0
9	16	10	7	0
10	60	42	15	1
11	48	28	8	0
12	30	13	2	0
Avg	37.2	24.1	10.5	1.8

Plant 1 had no runs of less than 20 hr on its design rate filter during the 9-month period. This plant, because of its geographic location on the lake and the location of its intake, undoubtedly has the best quality of raw water of any plant on Lake Michigan.

100 per cent, which resulted in shortened detention periods in the settling basins.

Plant 8, with an average of 61 hr, uses an anthracite filtering medium. This material, with its very large effective particle size, can be assumed to permit deeper penetration in the bed

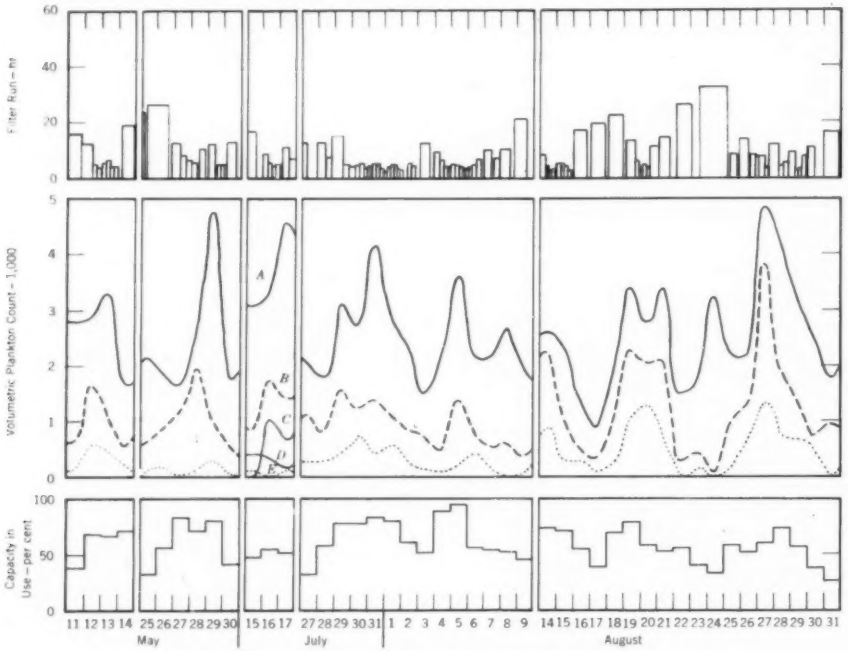


Fig. 3. Typical Short Filter Run Operation at Plant 2

Curves A, B, C, D, *and* E *represent total raw-water plankton, total settled-water plankton,* Melosira, Synedra, *and* Tabellaria, *respectively.*

Plant 2, which had a 16-hr average, had inadequate settling facilities, and Plant 4, which also had an average of 16 hr, had no operable slow mixing facilities.

Plant 6, with an average of 18 hr, did not operate at less than 75 per cent of design capacity and much of the time was operating at more than

with a subsequent reduction in clogging tendency.

Plant 9 uses an upflow basin and apparently obtains good settling efficiency, as is indicated by its average run length of 52 hr.

Plant 10 is a plant with considerably more capacity than is normally required, and it seldom operates at

more than 50 per cent of design capacity. This should provide detention periods of up to 10 hr, but short-circuiting was discovered in the settling basin, which reduced detention time to as low as 45 min. In addition, as the plant has excess available capacity, it is more economical to use additional wash water than to increase run lengths by use of heavier coagulant dosage.

20 hr when the plant was operating at less than 25 per cent of capacity. Table 3 also shows that one plant did not operate at more than 50 per cent of capacity and four did not operate over 75 per cent during most of 1958. On the other hand, four plants operated at as much as 125 per cent of capacity and two operated at 150 per cent. Plant No. 6 did not operate at less than 75 per cent of capacity.

TABLE 3

Summary of Short Filter Runs versus *Plant Capacity*

Plant No.	Percentage of Runs Shorter Than 20 hr					
	Plant Capacity in Use					
	0–25%	25–50%	50–75%	75–100%	100–125%	125–150%
1	0	0	0			
2	26	55	95	100		
3			7	39	82	
4		20	45	83		
5		24	57			
6				60	73	60
7		14	29	52		
8		2	7	25		
9	6	31				
10	59	68				
11		8	18	50	69	67
12		4	23	34	77	
Avg	22.8	18.8	25.6	55.4	75.0	63.5

It is interesting to note that 945 runs, or 37.2 per cent, of the 2,542 runs were less than 20 hr in length and 46 runs, or 1.8 per cent, were less than 5 hr, with seven plants having no runs shorter than 5 hr. Plant 2 experienced 35 runs less than 5 hr long, or 12 per cent of the total.

If run lengths of fewer than 20 hr are compared with percentages of plant capacity in operation, it is noted that nine plants had no runs shorter than

A comparison of alum and ferrous sulfate treatment was made on Plant 6 data. The filter run summary in Tables 1–3 does not include the results of the iron treatment as it shows only a comparison of alum treatment at all the plants. It is interesting to note, however, that a test filter at this plant, which used ferrous sulfate coagulant and filtered at a rate of 2.0 gpm/sq ft, had only 270 runs, with an average run length of 23.8 hr during the

9-month period. Alum treatment, by comparison, required 368 runs and had an average length of 18.5 hr. This represents nearly a 30 per cent increase in the average length of filter runs using ferrous sulfate. More careful control of the plant is required when iron is used, but it would appear that, as the costs of the two types of treatment are about the same, careful consideration should be given to its general use.

Data Analyses

One study was made to obtain information on growth cycles of the diatoms and when peak plankton counts occurred and to correlate these data with the occurrence of short filter runs and with percentages of plant capacity in use. The particular plant selected for this and other studies, Plant 2, was chosen because of weather and water quality conditions experienced during 1958 which were peculiar to the area. A localized drought induced high consumer demand. Coincident with this demand, low turbidity, high plankton counts, and short filter runs were experienced. The year 1958 was unusual in that the remaining plants did not have similar demands or water quality conditions. Figure 3 shows several excerpts from this study. A bar graph shows percentage of plant capacity in operation each day. The plankton count curves are not completely accurate, as only one sample per day was collected for counting. These samples were taken between 12 and 3 PM each day, when plankton populations are normally at their peak.

It appears that at this plant, whenever demand equals or exceeds about 60 per cent of capacity, short filter runs are likely to occur, even though plankton concentrations may not be extremely high. Turbidity in the raw water during the entire 9-month period was insignificant, ranging from 1 unit to a maximum of 5 units. Settled-water turbidity was 0–2 units. Raw-water pH and alkalinity remained nearly constant; the values for pH were 8.0–8.4, and, for alkalinity, 106–113 ppm. The required chlorine dosage ranged from a minimum of 0.8 ppm to a maximum of 1.9 ppm during critical periods. An examination of the several periods of short filter runs shown in Fig. 3 reveals the following conditions:

1. *May 11–14, 1958.* Plant design capacity in operation increased from 39 per cent on May 11 to 68 per cent on May 12, and remained more than 65 per cent for the next 2 days. Total raw volumetric count was not excessive on May 12, but, as demand on the plant increased, percentage removal decreased from 77 per cent on May 11 to about 42 per cent on May 12. *Tabellaria* also increased on May 12 to 600 organisms/ml (standard cubic units).

2. *May 25–30, 1958.* Similar observations can be made for this period as were made in period No. 1, above, except that on May 27–28 settling efficiency averaged about 35 per cent. *Tabellaria,* however, was low, zero and 150 oganisms/ml respectively.

3. *Jul. 15–17, 1958.* Demand on the plant was 55 per cent of design capacity. Settled-water plankton count was not extremely high; settling efficiency was about 47 per cent, which is poor, but *Tabellaria* was very low. An inspection of other organisms reveals that *Melosira* was high, 1,050 organisms/ml, and *Synedra,* 350 organisms/ml.

4. *Jul. 27–Aug. 9, 1958.* This period was the most severe one during the

entire 9 months. The two periods of short runs during this interval closely follow the high demands on the plant, which range from 80 per cent to 95 per cent of design. During the first period of short runs, Jul. 29–Aug. 2, the plant was operating at about 80 per cent of capacity. Raw-water plankton counts were fairly high and settling efficiency ranged from 42 per cent to 63 per cent. *Tabellaria* varied between 300 and 750 organisms/ml. The second period, Aug. 4–6, had similar characteristics, but plant capacity in use was more than 90 per cent of design, and *Tabellaria* was at a lower level.

5. *Aug. 14–31, 1958.* It appears that, in each of the three occurrences of short runs, relatively poor removal of plankton was experienced—that is, 13–55 per cent. There is additional evidence that when demand on the plant rises to 60 per cent of capacity or more, plankton counts are high and filter runs are short. One exception to the general trend was on Aug. 24; demand was low and raw-water count was relatively high, but removal was good and one filter run lasted more than 30 hr.

Several observations may be made from Fig. 3. Although the days of low demand are usually Saturday and Sunday during spring and summer months, low plankton counts occurred on these days—with one exception. On the other hand, high raw-water plankton counts, relatively poor removal, and plant production of more than 60 per cent of capacity go hand in hand and appear to produce short runs.

During the periods of short filter runs, it was noted that plankton removal was, for the most part, relatively poor. This may have resulted from poor settling efficiency and improper adjustment of coagulant dosage. Another factor of plant operation is also involved—that is, the velocity gradient of the water passing the flocculator blades. The work of Camp and Stein [2] showed that when flocculators are operated at speeds which produced an optimum velocity gradient for the raw-water temperatures encountered, floc formation and settling are considerably improved. For Lake Michigan water temperatures, which range from about 33° to 70°F, computations indicate that the optimum speed of the flocculators at Plant 2 would be 3.0–3.7 rpm. The flocculators actually operate at 2.60 rpm, which is a speed suitable for a water temperature of 95°F.

Further Analyses

Based upon the foregoing observations further analyses were made of the relationships between plankton organisms, the length of filter runs, and various plant production increments. This was accomplished by averaging all volumetric plankton counts for settled water from runs of 2-mil gal production and a 5-hr filter run length increment. The total range of filter operation and plant production was covered in this manner for the design rate filter. The summary of the analysis is shown in Table 4.

Generally, the plankton concentration decreases as the filter run length increases for any specific plant production increment. This lends support to the theory of the clogging ability of plankton. Several exceptions occur, however, particularly above the 10–12 mil gal capacity level of the plant. It would also be anticipated that at any specific filter run length, the plankton counts would be very nearly equal regardless of water production. This is

not the case. At 0–5 hr, the average volumetric plankton concentration varies from 1,232 to 1,745; at 5–10 hr, the range is 723–1,392; and at 10–15 hr, the range is 690–1,347. These variations are considerable and, in view of the constant 2.0 gpm/sq ft rate of application, the indication is that some factor in addition to plankton contributes to the clogging of the filter.

With the appearance of these variations, further detailed examinations were made of the individual plankton organisms with respect to the same parameters. Figure 4 shows curves of plankton concentrations as determined by the method of least squares transferred to a semilogarithmic plot.

It has been reported[3,4] that *Tabellaria* has the highest plankton population of any organism in the sand filter surface samples. The relationships shown in Fig. 4 certainly support this report. In fact, with the lone exception of *Cyclotella*, none of the other organisms has any appreciable variation through the entire range of filter run lengths. Not too much importance should be given to the effect of the *Cyclotella*, because at maximum concentration it averages only 135 organisms/ml.

There are, no doubt, many combinations of organisms that may clog a filter for a specific run, as indicated by the curve for total diatoms. Evidence points to *Tabellaria*, however, as the single plankton form which may cause a major portion of the troubles with Lake Michigan.

TABLE 4

Volumetric Plankton Count Averages for Varying Filter Runs and Plant Productions, Plant 2

Length of Filter Runs *hr*	Production—*mil gal*						
	4–6	6–8	8–10	10–12	12–14	14–16	16–18
	Plankton Count—*standard units/ml*						
0–5			1,745	1,550	1,633	1,232	1,275
5–10		723	1,066	1,392	1,330	1,217	1,220
10–15		690	1,088	954	1,347	1,032	
15–20	555	688	853	1,391	570	1,300	
20–25	693	639	909		1,115		
25–30	748	770	740	1,633			
30–35	273	530	642				
35–40	380	458	530				
45–50	320	410	275				

Other Causes of Clogging

It does not appear that the settled-water turbidity contributes to clogging of the filters, as, over the 9-month period, the average was less than 1.0 unit. The factors that may be ancillary causes of short filter runs could be the nannoplankton population (very small plankton), possible activation of the silica shell of the diatoms by a metabolite or other mechanism to form some type of silica gel, or the excreta or metabolite generated by the microorganisms and acting as a gelatinous cement. These suggestions bear in-

vestigation and have some corroborative support. There are indications, for example, that the nannoplankton concentration in lake water may have a total volume equal to or greater than the total volume of the larger plankton.

Improperly applied or generated activated silica has been reported as a direct cause of filter clogging. The gel could not be measured as turbidity in the settled water by the usual instruments, but a Tyndall beam would qualitatively show the presence of the myriad gel beads. If, as suggested, the silica shell of the diatom can be activated, it may produce a much greater clogging effect on a filter than a nondiatomaceous plankton form.

On one recent occasion, Plant 1 experienced a 50 per cent reduction in filter run length. The raw-water quality at this plant is exceptionally good, the water having very low plankton counts (less than 150 clumps/ml), low chlorine demand (less than 0.15 ppm), and low turbidity (less than 2.0 units). As a result, there are many times when the water is not chemically treated, but only chlorinated, settled, and filtered. This was true at the time of the aforementioned 50 per cent reduction in run time, except that the settled-water turbidity was less than 0.1 unit. A sample of this settled water was subjected to an improvised Tyndall beam and a very large quantity of minute suspended particles was observed. It is believed that these unidentified particles were largely responsible for the shortening of the filter runs.

A similar Tyndall beam test was made at Plant 2 on the same day. Plant capacity in use was less than 50 per cent with a settled-water turbidity of less than 1.0 unit. Run lengths were longer than 20 hr. The test revealed that no minute particles were present. While the filter is operating at more than 60 per cent of capacity, however, short filter runs are experienced. It is suggested that at this level minute particles are present, and that because of shortened detention periods in the flocculating and settling basins these particles are not removed. This would tend to explain the variations of plankton concentrations at different plant production increments as outlined in Table 4.

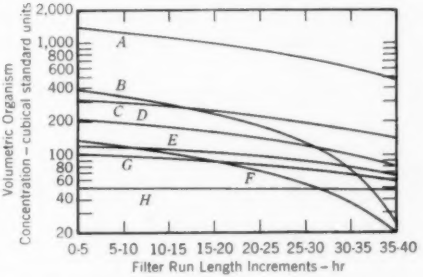


Fig. 4. Relationship of Significant Plankton Organisms to Filter Run Length

Curves A, B, C, D, E, F, G, *and* H *represent total diatoms,* Tabellaria, Melosira, Synedra, *nondiatom algae,* Cyclotella, Fragilaria, *and* Asterionella, *respectively.*

Cost Estimates

To examine the estimated cost of short filter runs to the participating plants, the following conditions were assumed:

1. That examination of the data and cost estimation were made on the total plant capacity at a 2.0-gpm/sq ft design rate

2. That chemical, power, and miscellaneous costs were based on an average of $10 per million gallons

A salary increment was not included, as the existence of short filter runs

does not have any material effect on this cost.

The data from fourteen separate filters were used to make a cost estimate for the twelve plants (Table 5). The additional filters for Plants 5 and 6 were included, as a considerable variation in overall operation occurs when these filters are considered.

The wash water used for these filters at each plant was computed on the basis of the percentage of plant production for all filter runs of more than 20 hr for the 9-month period. Average wash water percentages were also obtained for filter run increments of 0–5, 5–10, 10–15, and 15–20 hr. These percentages are shown in Table 5. It will be noted that there is a rather wide variation between the values shown in the sixth column. Plant 4, with 4.51 per cent, illustrates the effect of inadequate mixing facilities. Plant 9, which has upflow mixing and settling basins, exhibits the lowest percentages of wash water usage throughout the entire range of operation.

It must be kept in mind that the short filter runs generally occur during the warm-weather periods of peak demand and reduce the net volume of water that can be produced.

The second column of Table 5 shows that the percentage of wash water used averages as high as 13.3 per cent of the total water produced. At times, however, individual runs have required 20 per cent wash water.

Unless some satisfactory solution is found through improved design and operating procedures, costs will be increased further by the plant expansion necessitated in part by excessive wash water demands.

Additional costs owing to excessive water requirements are: (1) wash water production cost; (2) loss of potential revenue; and (3) plant expansion requirements. In order to calculate costs, the total excess wash water required for plant design operation (Table 6) is determined from the average wash water percentages shown in Table 5. Evaluation of the costs shows that:

1. Total excess wash water of 1,252 mil gal, produced at $10 per million gallons, gives a production cost of $12,520 (This amount is relatively insignificant in the light of other cost factors.)

2. The loss of potential revenue, based on the sale value of the product, is a maximum of $213,563 (This amount becomes very significant when it is remembered that it represents water that cannot be made available for distribution because of plant operating requirements.)

TABLE 5

Average Percentages of Wash Water Used at Filtration Rate of 2 gpm/sq ft

Plant No.	Filter Run Increments—*hr*				All Filter Runs Greater Than 20 hr
	0–5	5–10	10–15	15–20	
	Wash Water—*per cent*				
1				5.30	1.31
2	12.1	7.93	4.86	3.70	2.50
3		5.23	4.00	2.88	1.95
4		10.50	7.58	5.78	4.51
5(a)		6.38	4.22	3.08	1.56
5(b)	8.5	6.30	3.87	2.93	1.55
6(a)	8.4	4.80	3.82	2.64	1.35
6(b)	10.3	5.97	3.78	2.36	1.20
7	13.3	7.58	5.35	3.75	2.10
8				5.70	1.78
9		4.23	2.83	1.98	1.01
10		5.70	4.10	2.80	1.90
11		6.10	4.10	2.80	1.50
12		8.60	5.80	4.80	2.80

3. The total excess wash water required is equal to an average of nearly 4.5 mgd spread over the entire 9-month period (This is equivalent to the average daily demand of a city of 30,000–35,000 population. Additional capacity of this magnitude would normally be created only by plant expansion. If the cost of this increase in water production caused by short filter runs were added to the existing cost, it is possible that the utility would be forced to operate at a loss.)

Needless to say, any business organization providing service to a consuming public must show a favorable return on costs. No organization can survive for long when operating at a loss. Yet this is precisely what happens when the filter runs drop below the economic breakpoint. Proper design, based on water quality, total expected population use, and a standard design unit, would no doubt eliminate the need for a good many unforeseen plant expansion programs.

Treatment Index

No study involving the determination of the factors responsible for the clogging of sand filters would be complete without suggestions for a possible method of predicting trouble in any treatment plant. This subject is being investigated as a part of the project. A reliable index that would correlate chemical dosage, coagulation, settling, and filtration with concentrations of filter clogging entities in raw and settled water would be most desirable. Better treatment at lower cost would result from the quantitative control afforded by such an index. The index would also be of value in research and highly desirable for use in water filtration plant design.

Experimental work has been conducted in various laboratories for several years to develop such an index. AWWA Task Group 2720-P was established to study and evaluate laboratory techniques and equipment used in this work. To date, however, no conclusions have been reached by the task group.

The filtrability index, as originally developed by Boucher in England,[5] is the ratio of the increase in hydraulic resistance due to flow through a filter to the volume filtered. Experiments were conducted at Northwestern University using equipment based on the original designs of Boucher. This equipment was built so as to include woven wire fabric discs, having pore sizes of about 20 μ, through which samples of water are passed and the head loss is measured.

TABLE 6

Estimated Loss in Revenue for Wash Water at Design Rate

Plant No.	No. of Filters in Plant	Total Excess Wash Water Used for Plant *mil gal*	Consumer Cost per 1,000 gal	Loss of Revenue to Plant $
1	8	0.500	0.223	111
2	9	49.77	0.199	9,900
3	32	167.00	0.124	20,800
4	10	19.90	0.263	5,240
5(a)	12	19.60	0.280	5,500
5(b)	6	55.38	0.280	15,500
6(a)	50	678.00	0.160	108,300
6(b)	30	153.60	0.160	24,600
7	6	40.60	0.435	17,680
8	6	0.378	0.184	74
9	12	3.93	0.387	1,518
10	4	8.12	0.400	3,240
11	20	42.00	0.191	8,000
12	6	15.50	0.200	3,100
Total	211	1,252.28		213,563

Values of the index obtained with this apparatus were plotted against several different variables, such as total raw-water plankton counts, total settled-water plankton counts, and the filter performance index. Trends were observed, but, because of the scattering of plotted points, it was considered that the data were not reliable. The relatively large size of the pores in the filter discs probably permits many organisms and some turbidity particles to pass through the filter before a sufficiently dense mat is formed to collect all material. Any uneven distribution of organisms in a given sample, or an unknown amount of small suspended solids that were not collected, would cause the results to be erroneous and inconsistent.

The foregoing difficulties necessitated a change in procedure. The use of the wire disc filters has been abandoned, and a technique is being tried using membrane filters. The pore size of the molecular filter membrane, approximately 0.5 μ, is small enough to trap more of the solids, including colloids and plankton. In this method, known volumes of settled water are filtered under constant vacuum, and the time is recorded. In addition, the total plankton count is determined and the weight of the dried membrane filter, together with the solids and organisms, is obtained. Plots of data gained by this method reveal that plankton alone do not necessarily create sufficient clogging to increase the time of filtration. In fact, some tests have shown that when plankton counts were high filtering time was less than at lower counts. This indicates that the plankton on the membrane filter were perhaps acting as a filtration aid rather than a clogging agent.

One deficiency has been found in the membrane filter method. The ability to separate plankton and suspended solids in a given sample when a single membrane filter is used appears to be essential, if one is to evaluate the relative significance of each, but it cannot be done. Centrifuging of the samples at various speeds and for different periods of time does not accomplish the desired separation. An attempt is now being made to revise the technique in order to evaluate the two variables properly.

Two possibilities appear to have merit: (1) the addition of some chemical to the sample, so that either the suspended solids or the plankton will agglomerate sufficiently to settle out during centrifuging, while the other is held in suspension; or (2) the use of two or more membrane filters in series having pore sizes ranging from 0.5 μ to perhaps 4–5 μ, in order to separate materials of different particle sizes on the filters. Several trials of the latter method have been made using two membrane filters of 0.5- and 5-μ pore size. Results of these trials show that 15 per cent (by weight) of the solids and organisms are retained on the larger-pore filter, and 85 per cent are retained on the smaller-pore filter. This technique is currently being studied further.

Polyelectrolytes

Various types of polyelectrolytes have been proposed to aid coagulation, improve treatment, and lower cost by substantially reducing quantities of the common chemicals currently used. If the unmeasured factors are as important as unconfirmed evidence indicates, the use of polyelectrolytes to "bridge" the particles so that they can

be effectively removed should be investigated thoroughly. It has been reported that considerable success has been attained with certain river and industrial waters, but very little experimental work has been done on Lake Michigan water.

The authors have conducted laboratory work on several polyelectrolytes when severe conditions developed on the lake owing to cold water and low turbidity. Jar tests were carried out under controlled temperatures and mixing conditions to simulate plant operations. The mixing paddle rate was calculated to correspond to operating conditions. Determinations of coagulation effectiveness were made on the basis of the appearance and settling qualities of the floc and plankton counts on raw and settled water.

Evaluation of the necessary chemical quantities did not indicate sufficient improvement to warrant further work with the particular polyelectrolytes used. This should not, however, obviate the need for further investigation of the effect of polyelectrolytes on Lake Michigan water.

Summary

This article has described and presented selected data and analyses from a study that is currently being made of the short filter runs on Lake Michigan. Because the field study is still in progress, investigation and analysis of data from all twelve filtration plants cannot be completed until all data are received and processed. Certain tentative conclusions may be drawn from the available data and from the results of already completed analyses:

1. The magnitude of the short filter run problem is indicated by the fact that 37 per cent of the runs for all of the test filters were less than 20 hr for the 9-month period studied.

2. The "clump count" procedure for algae determination has proved very satisfactory with respect to technician proficiency and time requirements. No difficulty is expected in the conversion of these data to volumetric equivalents with the use of the digital computing facilities.

3. *Tabellaria* is the most important of the Lake Michigan plankton that exhibit filter-clogging tendencies. High concentrations of other plankton in combination may be a factor, but no other single organism appears to be as significant.

4. The turbidity of the settled water has not been a significant factor in short filter runs.

5. It is suggested that nannoplankton, excreta from microorganisms, or siliceous gel may be possible factors contributing to short filter runs.

6. Adequate flocculation and sedimentation are needed throughout all operating ranges up to the design capacity at a plant, if proper treatment is to be effected.

7. The length of filter runs shows marked increases when ferrous sulfate is used for coagulation instead of alum. This was effectively demonstrated at Plant 6.

8. The overall loss in revenue to the participating plants is estimated to be $226,000 for the 9-month period. This includes the $12,500 for excess wash water production costs.

9. The need for a satisfactory quantitative treatment index to replace the qualitative measurements now in use for treatment plant control is demonstrated.

10. The use of polyelectrolytes should be more thoroughly investi-

gated as a possible supplemental treatment during short filter run periods.

Acknowledgments

The authors wish to acknowledge the assistance and cooperation of the operating personnel of the twelve filtration plants, the research committee of the West Shore Water Producers Association, personnel of the Great Lakes Research Institute, and of USPHS. Particular acknowledgment is due to H. W. Poston and C. M. Palmer, both of USPHS, for their untiring efforts, helpful suggestions, and constructive criticism.

References

1. BAYLIS, JOHN R. Microorganisms and Short Filter Runs. *Pure Water*, 10:184 (Dec. 1958).
2. CAMP, THOMAS R. & STEIN, P. C. Velocity Gradients and Internal Work in Fluid Motion. *Boston Soc. Civil Engrs.*, 30:219 (Oct. 1943).
3. BAYLIS, JOHN R. Effect of Microoganisms on Lengths of Filter Runs. *Wtr. Wks. Eng.*, 108:127 (1955).
4. BAYLIS, JOHN R. Microorganisms That Have Caused Trouble in the Chicago Water System. *Pure Water*, 9:47 (Mar. 1957).
5. BOUCHER, P. L. New Measure of Filtrability of Fluids With Applications of Water Engineering. *J. Inst. Civil Engrs.*, 27:415 (Feb. 1947).

Coagulant Aids for Potable-Water Treatment

The USPHS Technical Advisory Committee on Coagulant Aids for Water Treatment has added the following products to the list of those that may be used for water treatment—in the concentration recommended by the manufacturer (1 ppm)—without adverse physiological effects on the consumers: Separan NP10, potable-water grade, and Purifloc N17, both manufactured by the Dow Chemical Co.

The committee's findings bear only on the health aspects of the use of these products and do not constitute an endorsement or indicate their effectiveness in the proposed use. The names of other coagulant aids on the committee's list were published in the February 1959 issue (p. 233) and the May 1959 issue (p. 574) of the JOURNAL.

taste and odor problems on your mind?

STOP COMPLAINTS with ECONOMICAL

AQUA NUCHAR

ACTIVATED CARBON FOR TASTE AND ODOR CONTROL

In plant after plant, operators prove the most effective way to control tastes and odors is by daily threshold odor tests and AQUA NUCHAR Activated Carbon.

With 800 square yards of surface area per gram, AQUA NUCHAR quickly and economically traps and eliminates taste-and-odor-forming substances . . . leaves treated water "sweet" and sparkling. Properly applied, it is the only method universally effective against taste-and-odor-forming substances commonly found in water supplies.

AQUA NUCHAR is stocked for 12–24 hour delivery from 25 strategically located warehouses.

If you have taste and odor problems on your mind, phone or write us today. Our field technical service staff is always ready to survey your plant.

industrial CHEMICAL SALES

division west virginia pulp and paper company

230 Park Ave., New York 17 · Philadelphia National Bank Bldg., Philadelphia 7

35 E. Wacker Dr., Chicago 1 · 2775 S. Moreland Blvd., Cleveland 20

FINANCIAL PROTECTION

for your most vital service

Water . . . your community's most important single service . . . must be protected by sound financing. The only *sure* protection is the sustained accuracy of your water meters.

If a meter becomes inaccurate, it starts to give away revenue. In home after home, leaks and carelessness go scot-free. The warning voice of the meter is gradually stilled, and wanton waste soon uses up your available water supply.

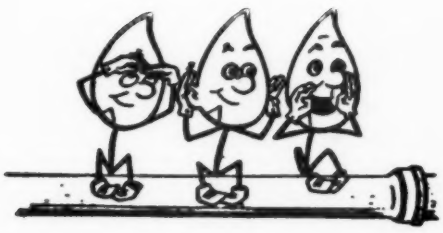
Worse yet, lack of proper income makes it impossible to build new capacity without tremendous losses. Water shortages soon become critical. Your city's development program soon dies . . . of thirst.

How guard against this? Set up a good meter testing and repair program. Pick meters that stay accurate longer. Talk to your meter superintendent . . . the man whose efforts guard your water supply. Ask which brand of meter consistently gives highest sustained revenue . . . with lowest repair and depreciation. We sincerely believe your answer will be "Trident."

2818

NEPTUNE METER COMPANY
19 West 50th Street • New York 20, N. Y.
NEPTUNE METERS, LTD.
1430 Lakeshore Road • Toronto 14, Ontario
Branch Offices in Principal American and Canadian Cities.

neptune
TRIDENT WATER METERS



Percolation and Runoff

Happy New Year, we say, and a happy new year it promises to be, too, for the water supply field, as more and more public attention is focused on its problems.

● First focuser these days is Senator Robert S. Kerr (D., Okla.), whose Senate Select Committee on National Water Resources has been canvassing the country for the facts and figures on water supply and demand, present and prospective. By the time the committee reports, sometime before Jan. 31, 1961, its hearings, investigations, and statements will have done much more than develop the information upon which legislation can intelligently be based; it will have given water supply more than a year of limelight, the rays of which are known to exercise a loosening effect upon public purse strings.

Along the resources front there are more local focusers, too: In California, all waterdom is organizing its efforts to sell the 1.75-billion-dollar bond issue needed to finance the Feather River Project, first unit of the 11-billion-dollar California Water Plan. In New Jersey, citizens' groups and the press have been active in publicizing progress on the dams made possible by a successful 1958 bond referendum, and in keeping alive the public interest and concern aroused during the referendum campaign through public discussion of the establishment of a federal-interstate agency with broad powers to administer the water resources of the Delaware River, the most promising additional source of supply for New Jersey, as well as for New York, Pennsylvania, and Delaware. In Texas, State Board of Water Engineers' efforts to sell a master plan for water supply are being somewhat hampered by full reservoirs, but memories of the state's worst drought, that broke only 3 years ago, are being counted upon to rally public support. As a matter of fact, from the headlines of a recent Associated Press series—"Boom in Population Brings Water Worries for East," "Water Troubles Plaguing South," "Water Crisis Ahead for West," and "Water Need Perils Growth in Midwest"—we get the distinct impression that everyone everywhere has water problems and is beginning to focus interest on them—the first step in doing something to solve them.

● A wide-lensed focuser, certainly, has been the Department of Interior's Office of Saline Water, whose $10,000,000 demonstration plant program is arousing more interest in water

(Continued on page 36 P&R)

(Continued from page 35 P&R)

supply than could a public relations program costing ten times as much, not to mention the progress it is fostering in the conquest of the technical problems involved in making desalinzation more generally practical from an economic standpoint. In its 7 years of existence, the Office of Saline Water has sponsored and encouraged a great amount of technical progress—progress that has brought into view a new source which the public water supply field must take into serious consideration. And it matters little that for the present, at least as far as sea water is concerned, the interest aroused by desalinization is likely to be of considerably more benefit to public water supplies than is desalinization itself.

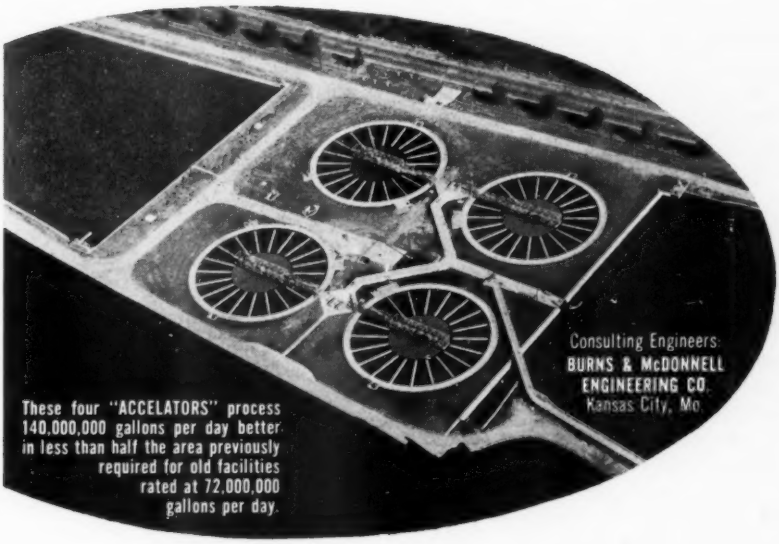
● Doing its focusing full time and full tilt, too, has been the USPHS Div. of Water Pollution Control. Although some of its activities may seem to approach public water supply problems from the rear end, all of them and all of the supporting activities by regional, state, and local agencies have had at least an indirect effect in making the public more conscious of the water it drinks. So if it is sometimes the damage to a wildlife refuge by meat-packing wastes that the USPHS emphasizes in its publicity, or if Orsanco gives top billing in its annual report to the $100,000,000 sewage treatment plant recently completed by Pittsburgh, or if local pollution controllers give the headlines to the protection of recreational facilities, water supply is still in the picture to reap benefit not only from the publicity but from the action publicized.

● And final focuser is the acrimonious aggregation of fluoridation fighters everywhere. The proponents, among them, in selecting water supply as the vehicle for fluoride, pay tribute to its universality; in selling fluoridation as "another public health benefit of water supply," call attention to its present benefits; in citing the assurance of safety, praise the technical competence of water utility operators. And the opponents are, if anything, more complimentary in protesting any change in the "pure, wholesome, good-tasting" public water supply. In New York City, for the third time, the battle is now on again, with the Committee to Protect Our Children's Teeth on one side and the Assn. for the Protection of Our Water Supply on the other. Whatever the outcome of New York's battle and whatever has been the outcome of at least 3,000 other fluoridation free-for-alls, and whatever suffering such struggles have inflicted on the water supply personnel involved, awareness of public water supply is thereby promoted.

● Of these four focuses on water supply, unhappily, only fluoridation does not focus on some present inadequacy. It will certainly be a happier new year when this stage is over—when public attention has become public support, that is, and adequacy is assured. But for now, a Happy New Year is, indeed, in focus.

The meter reader's lot, long an unhappy one by reason of dogs, both canine and pedal, and by reason of customers, both unreasonable and absent, had taken a turn for the worse during the past year or so with the threat of extinction by the substitution of electronic meter-reading devices. Now it is good to report signs of a resurgence of the humanic type. First, at AWWA's San Francisco Conference last July, Badger Meter Mfg. Co.,

(Continued on page 38 P&R)


These four "ACCELATORS" process 140,000,000 gallons per day better in less than half the area previously required for old facilities rated at 72,000,000 gallons per day.
Consulting Engineers:
BURNS & McDONNELL ENGINEERING CO.
Kansas City, Mo.

OMAHA CHOOSES INFILCO EQUIPMENT for World's Largest High-rate Water Treating Plant

... saves hundreds of thousands
... doubles production in half the space with latest ACCELATOR® clarifying units

The Metropolitan Utilities District of Omaha and their Consulting Engineers, Burns & McDonnell, selected solids-contact units for the treatment of Missouri River water because extensive studies and evaluation of competitive bids proved that ACCELATOR® units provided the greatest capacity in the limited space available.

Each "ACCELATOR" basin is 120′ in diameter by 27′6″ deep. Each is guaranteed to produce high quality effluent at minimum chemical cost and have a capacity of 35 m.g.d. with water temperature above 65° F. or 20 m.g.d. below 35° F.

Performance tests have demonstrated that each "Accelator" unit will clarify 41 m.g.d. with water above 65° F. and at least 31 m.g.d. with 35° F. water—using even less chemicals than were indicated in laboratory jar tests; and produced effluent turbidities substantially less than 10 ppm. Subsequent operation under hardness reduction conditions has produced even better results.

These are typical of the results being obtained in more than 2500 "ACCELATOR" installations, treating every type of water for municipal and industrial use. For more complete information write today for Bulletin 1825-D.

Inquiries also invited on coagulation, precipitation, sedimentation, filtration, flotation, aeration, ion exchange and biological processes.

INFILCO INC., General offices — Tucson, Arizona
Field offices throughout the United States and other countries

INFILCO

Eminence in design for water, sewage and waste treating and processing equipment... since 1894

(Continued from page 36 P&R)

Milwaukee, Wis., introduced a remote meter register that can be mounted out of dog and customer range. Then, at Rock Falls, Ill., in September, the local water department announced "the world's first use" of remote registry in water meters in an installation of somewhat similar equipment manufactured by Visi-Meter, Inc., Kansas City, Mo., on 1,500 customer meters in its system. Next, in October, the Lincoln Park, Mich., Water Dept., using the Badger equipment, made remoteness even more convenient by grouping meters (see Correspondence, this issue, p. 92 P&R). And, finally, at Belleville, N.J., also in October, the town commission introduced an ordinance requiring home owners to make water meters more accessible to meter readers.

Next thing you know, Nevada will repeal its law banning the use of water meters, if not meter readers, in communities of 5,000 or more population.

The 1960 Nuclear Congress, to be held at the New York Coliseum the week of April 3rd, will, as in previous years, include a session on water supply and waste disposal. Headed by E. Shaw Cole, AWWA Publication Committee chairman, and Ralph E. Fuhrman, FSIWA executive secretary, the session is tentatively scheduled to include the following papers:

1. "Environmental Radioactivity in Large Area Surrounding Nuclear Electric Plant," by John V. Nehemias, director of radiological health surveys, National Sanitation Foundation

2. "Strontium 90 in Surface Waters," by C. P. Straub, L. R. Setter, and P. F. Hallbach, Taft Sanitary Engineering Center

3. "Use of Tritium as a Tracer in Evaluating Waste Discharges," by Warren J. Kaufman and Richard M. Hours, University of California

4. "Hanford Reactor Effluent Contribution to Environmental Radiation Dose," by Robert L. Junkins, General Electric Co.

A fish story to end all fish stories came out of Skelton Green, England, last month, but local authorities didn't really permit it to end. As a matter of fact, as soon as reports were received that "little four-legged fish that eat each other" were pouring from the village water taps, J. H. Rhodes, public health inspector for the urban council, began an investigation. And, although he was unable to identify the creatures, which council chairman Tom Dalton described in the following words:

> The fish are about a quarter of an inch long. They have legs. They are cannibals, and it is possible with the naked eye to see them gobbling each other up.

he took the unimaginative way out and prescribed extra chlorine. We'd have waited until they all ate each other up.

A fish story that was ended, at least temporarily, but we hope permanently, by the Taft-Hartley Law, is the one that came out of Pittsburgh on Sep. 29. That was the news that bass, blue gills, and minnows were returning to the Monongahela, Ohio, and Allegheny rivers as the steel strike went on and on. It might have resulted from the lack of steel for fish hooks, of course, but we understand that it was ascribed to the absence of acid wastes in the streams. All of which suggests that

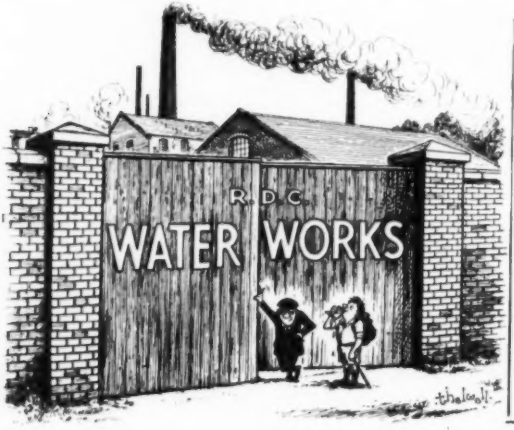
(Continued on page 40 P&R)

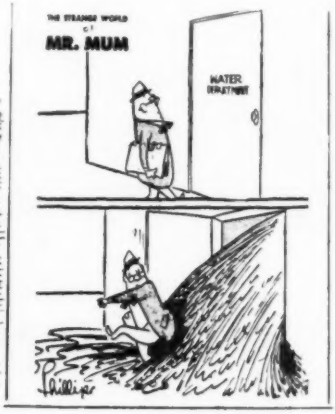
You buy
greater
DEPENDABILITY
with
WATCH DOG
WATER METERS
WATCH DOG
GAMON METER DIVISION
NEWARK
NEW JERSEY
WORTHINGTON

(Continued from page 38 P&R)

anglers will share with water suppliers the little good that the ill wind of continued dissension in the steel industry can bring.

Britain's drought, which has been bad enough to interfere with activities as varied as whisky manufacture and baptism (see November P&R, p. 46), was in direct contrast to the weather in most of the US in 1959. Evidence, perhaps, of this difference is provided in the cartoons reprinted below, the one from *Punch*, the other from the Detroit *Free Press*.





In water closets the accent is too much on "closets" these days, according to not only us, but Paul McCobb, leading industrial and home furnishing designer. Of course, *his* concern is less with the water itself than with the room to enjoy it, but if there is no longer room in the bathroom for a bath, *his* concern must be *our* concern, for baths still use almost 50 per cent more water than do showers.

The trend—let us call it "the Alden trend"—toward shrinking johns is apparently a misdirected attempt by architects and builders to offset the cost of expanding the kitchen and resurrecting the dining room in the modern home. But such Aldenism, McCobb points out, can save relatively very little in money and can lose relatively very much in comfort—particularly to the lady of the house, for whom lolling in the bath in an aura of soaps, salts, and cosmetics—not to mention water—"is one of the last obvious vestiges of female pampering." It is his thought that bathroom fixture manufacturers can help to reverse the trend by putting their most imaginative designers to work on more spacious equipage, but that it is women who must lead the way. And water utilities, we feel—at least those who are ready to supply all the water that customers need, when and where they need it—will help themselves by helping, for instance, in setting up local Priscilla units through which women can work together for johns that speak for themselves as representative of our modern standard of laving.

(Continued on page 42 P&R)

EXTRA SAFETY FACTOR!

CONSERVATIVE DESIGN is one of the important reasons why American Concrete Cylinder Pipe has gained such high acceptance by engineers and water works officials in the west. The composite design of the pipe is based on a factor of safety of 2¼ at the elastic limit of the pipe. American Concrete Cylinder Pipe will safely withstand sudden and severe increases of pressure – surge and water hammer – or the occasional concentrated external loadings met under unusual field conditions.

The *composite* action of the mortar lined steel cylinder, circumferential rod reinforcement and external mortar coating accounts for the consistently successful performance record of this type of pipe. The use of a minimum of 25% to, under certain conditions, 50% or more of the total required cross-sectional steel area as tension-wound circumferential reinforcement substantially increases the pipe's external supporting strength over that which would be obtained if all of the required steel area were placed in the cylinder alone.

Take advantage of American Concrete Cylinder Pipe's greater inherent strength through more effective use of materials – see an American sales engineer when planning your next project.

CONCRETE PIPE FOR MAIN WATER SUPPLY AND TRANSMISSION LINES

American PIPE AND CONSTRUCTION CO.

LOS ANGELES: 4635 Firestone Blvd., South Gate, Calif.— LOrain 4-2511 • **HAYWARD:** P.O. Box 630 — JEfferson 7-2072 • **SAN DIEGO:** P.O. Box 13 — CYpress 6-6166 • **PORTLAND:** 518 N.E. Columbia Blvd. — BUtler 5-2531 • **ALBUQUERQUE:** P.O. Box 1782 — CHapel 7-0486 • **PHOENIX:** American Concrete Pipe Co. (Subsidiary) P.O. Box 12127 — Alpine 2-7566

(Continued from page 40 P&R)

Rolf Eliassen, professor of sanitary engineering at Massachusetts Institute of Technology, has been in Europe on a mission for the International Atomic Energy Agency, setting up a research program on radioactive-waste disposal. The agency, which has its headquarters in Vienna, is an outgrowth of President Eisenhower's "Atoms for Peace" program. A second purpose of Dr. Eliassen's trip was to attend an international conference on radioactive-waste disposal in Monaco.

And now carrageeninated water to prevent ulcers suggests itself as a result of the research reported by Dr. John C. Houck, director of biochemical research at the Children's Hospital Research Foundation in Washington. The carrageenin is a tasteless, harmless seaweed extract which has been shown by animal experiments to prevent peptic ulcers when given in small amounts in drinking water. Actually, although the most effective dose will require the daily drinking of four glasses of water, no one has yet suggested that the water utility start carrying carrageenin residual through its mains. But if ulcer-producing problems and proclivities continue to multiply, we, ourself, may make the suggestion. As a matter of fact, carrageeninated water ought to be particularly beneficial to some of the bitterest of belligerents in the fluorida-

John W. Northcutt (second from left), assistant vice-president of Rockwell Manufacturing Co., Pittsburgh, Pa., is sworn in as adviser to the director of the Water & Sewerage Industry & Utilities Div. by BDSA Director H. B. McCoy (left). Others in the foreground are Luther L. Smith, Northcutt's predecessor (April P&R p. 46), and Walter L. Picton, director of WSIUD.

(Continued on page 44 P&R)

WHICH SIZE WILL SOLVE YOUR PRESSURE PROBLEMS?

Satisfactory water pressure through suitable storage facilities can be accomplished economically by calling on Graver. Graver fabricates and erects all sizes of elevated water tanks—in standard sizes ranging from 25,000 to 3,000,000 gallons—in special designs to fulfill unusual needs. Should a standpipe, a steel reservoir or a pump suction tank best solve your problem, Graver builds these, too. It pays to call on Graver's versatile craftsmanship!

GRAVER TANK & MFG. CO.

DIVISION—UNION TANK CAR COMPANY

Plants and Offices Across America

EAST CHICAGO, INDIANA

GRAVER®

(Continued from page 42 P&R)

tion fracas. And however administered carrageenin is bound to make water utility men less susceptible to ulcers, as well as better equipped to prevent them, by virtually assuring them of a sales boost that should average at least three glasses per capita per day, or nearly 25 mgd. Just drink your ulcers away.

Wendell R. LaDue, chairman of the AWWA Committee on Water Utility Administration and chief engineer of the Akron, Ohio, Bureau of Water Supply, has been appointed to a 3-year term on the Ohio Water Commission by Governor DiSalle.

'One man's poison . . .' is the theory on which a Japanese firm recently purchased one of those electrodialytic membrane units developed by Ionics, Inc., of Cambridge, Mass. Designed to produce fresh water from sea water, the unit is now labeled a concentrated salt brine machine, and it supplies brine in large quantity, with only a minor waste disposal problem in the fresh water involved. Lacking natural salt deposits, the Japanese plan to use such units in the production of salt that must now be imported. Our meat, of course, is more expensive.

Herbert S. Johnson Jr. has been appointed vice-president in charge of marketing for Nalco Chemical Co., Chicago. Replacing Johnson as manager of the industrial division is Leonard R. Robinson Jr.

(Continued on page 46 P&R)

You *Can't* Afford
PAINT DAMAGE

1. It Costs Money
2. Endangers Your Citizens

Only National Tank Maintenance Corp. "Special-Skil" Applicator crews protect you completely against paint damage. Our crews use a special paint roller—designed and patented for us. Our crews use DRI-MIST long lasting paints. National Tank exclusives . . . "Special-Skill" crews . . . our own design paint roller . . . and special long lasting DRI-MIST paints reduce damage . . . cut cost. You and your community benefit.

Our Engineering Department will furnish an estimate on your water tank without cost or obligation. Write, wire or telephone National Tank.

NATIONAL TANK
MAINTENANCE CORP.
1617 Crocker St.
Des Moines, Iowa
CHerry 3-8694

DARLEY MAGNETIC
DIPPING NEEDLE
$17.50

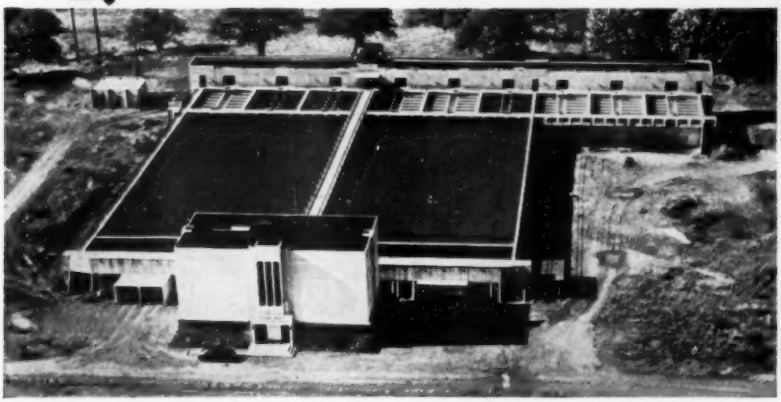
with 3 section
telescoping
handle
$22.25

Write Today for
100-Page Catalog

W. S. DARLEY & CO.
Chicago 12

10 YEARS' outstanding service!

Inertol® coatings protect Hayden Bridge Plant, Eugene, Ore.



RAMUC® MILDEW-RESISTANT ENAMEL, applied ten years ago, still guards 250-foot-long tunnel connecting head-house with pumping section. Flanked on either side by one million gallons of cold water in twin reservoirs, the warmer tunnel is subjected to heavy condensation and dripping. The front of the main building was painted with Ramuc Masonry Paint ten years ago. The concrete and steel filter beds in the rear of the plant are painted with Torex® Enamel every five years on a routine maintenance painting program. These are but a few of the many areas of this plant protected with long-lived Inertol coatings.

PACIFIC NORTHWEST'S LARGEST MUNICIPAL WATER PLANT, the 37.5 MGD Hayden Bridge installation serves over 60,000 persons in the fast-growing Eugene metropolitan area.

Inertol coatings, specified for this plant by consulting engineers Stevens & Thompson, Portland, safeguard surfaces against condensation, mildew, abrasion, submersion and weather.

SPECIFICATIONS FOR RAMUC MILDEW-RESISTANT ENAMEL. A glossy, mildew-resistant, chlorinated natural rubber-base coating, in color, for nonsubmerged concrete, steel and indoor wood surfaces.

Concrete Surfaces: *Colors:* color chart 560. *No. of coats:* one coat *Ramuc* Mildew-Resistant Enamel over two coats *Ramuc* Mildew-Resistant Undercoater. For flat finish, two coats *Ramuc* Mildew-Resistant Flat to bare masonry—omit Undercoater. *Coverage:* 250 sq. ft. per gal. per coat. *Approximate mil thickness per coat:* 1.2. *Drying Time:* 24 hours. *Primer: Ramuc* Mildew-Resistant Undercoater (2 coats). *Thinners: Inertol* Thinner 2000-A for brushing; 2000 for spraying. *Application:* Brushing: *Ramuc* Mildew-Resistant Enamel—brush type, as furnished. Spraying: *Ramuc* Mildew-Resistant Enamel—spray type, add sufficient Thinner 2000 for proper atomization.

Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from warehouse stocks in your area. Write today for free "Principal Types of Protective Coatings," a short course in practical paint technology. Ask for WW-754.

Write for specifications for steel surfaces and for Ramuc Floor Enamel Specifications.

Inertol®

Ask about Rustarmor,® Inertol Company's hygroscopically controlled rust-neutralizing paint.

INERTOL CO., INC.

484 Frelinghuysen Ave., Newark 12, N. J. • 27-G South Park, San Francisco 7, Calif.

(Continued from page 44 P&R)

Awash was one of the customers of the Indianapolis Water Co. recently when Carl Butterman of its staff snapped the photo above. But the inundatory state, we are told, was not the result of the water company's advertising campaign—outstanding though it is—or the laundry's living up to its apparent name. As a matter of fact, it must be obvious from the photo itself that nobody has put the bee on the Meadowbrook Laundry. Just good cleaning fun, that's all!

Warren A. Brown has been named president of R. D. Wood Co. and its parent firm, Florence Pipe Foundry & Machine Co., manufacturers of cast-iron pipe, fittings, hydrants, and valves. Brown succeeds E. Roy Russell, who has retired after 57 years with Florence.

Harry E. Kampf has been named chief engineer of the Liquid Meter Div. of Neptune Meter Co., New York. Kampf, who joined Neptune in 1933, has been active in the development of industry standards.

From potability to potamology is the route charted for an old pumping station which the Louisville (Ky.) Water Co. has agreed to lease to the University of Louisville at a nominal rental fee to house the nation's first, and only the world's third, potamological institute. Suited for this distinction by reason of its Corinthian architecture and its ideal location on the banks of the Ohio River, the three-story building will have its interior remodeled to provide classrooms and laboratories for potamological research, supported by the Ohio River Valley Water Sanitation Commission. Oh yes, potamology is the science of rivers, and the institute, if it receives the final approval of both organizations involved, would continue the research on the Ohio and its aquatic life that is now being carried on for Orsanco by the university. It would be operated as a branch of the university, with university officials at its head, but a member of the water company would be placed on its board of directors in the

(Continued on page 48 P&R)

MONTEREY SAND CO.

Crystal Amber Filter Sand & Gravel

"The Standard of the Industry"

In conformity with A.W.W.A. specifications for filtering material or made to your own specification.

Shipped Bulk or in 100 lb. bags.

Filtration specialists for over 15 years

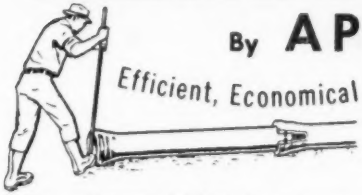
P. O. Box 928, Monterey, Calif. — Inquiries Invited

For The Best Connection You'll Ever Make—

ALTITE JOINT®

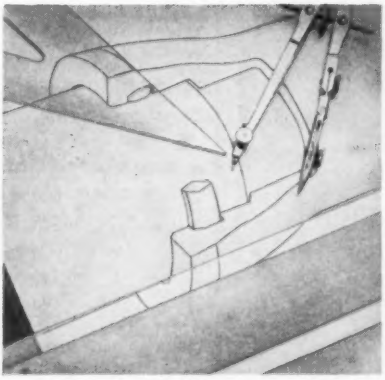
By APCO

Efficient, Economical and Fool Proof—



The **ALTITE JOINT** has been subjected to a series of rigid tests much more severe than are encountered under the most extreme installation and service conditions in the field. Even under extreme conditions, this joint is so simple to install—you could hardly go wrong if you tried.

Underwriters Approved
Patent Applied For.



For efficiency, Economy and Simplicity—

Order ALTITE For Your Next Job

SALES OFFICES

122 South Michigan Ave.
Chicago 3, Illinois

350 Fifth Avenue
New York 1, New York

905 1096 Grand Ave.
Kansas City, Mo.

18505 W. Eight Mile Rd.
Detroit 41, Mich.

5335 Southern Ave., South Gate, Calif.

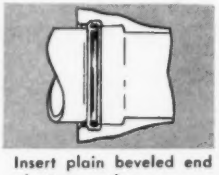
ALABAMA PIPE COMPANY

General Offices — ANNISTON, ALABAMA

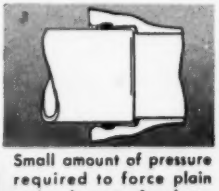
Four Operations As Simple As Failing Off a Log—

Insert Rubber gasket in bell end of pipe — you can't put it in wrong — A child can do it.

Wipe on a small amount of special lubricant—This reduces friction.



Insert plain beveled end of pipe — there are no grooves, ridges or tips on gasket to interfere with smooth insertion.



Small amount of pressure required to force plain end to bottom of socket—Your simple, time saving joint is completed.

HAYS

the Quality Line
IN
WATER
SERVICE
PRODUCTS

CORPORATION
STOPS

One of a
complete line of
Water Service
Products

GENERAL PRODUCTS DIVISION
HAYS MFG. CO.
ERIE, PA.

(Continued from page 46 P&R)

hope of completing the cycle by applying the knowledge from potamology to potability.

Harry A. Faber, USPHS research coordinator, has accepted an invitation from the International Water Supply Congress (meeting in Berlin in 1961) to serve as "general rapporteur" for the subject of water disinfection. In this capacity, he will organize a committee of "national rapporteurs" from various countries and compile a report for presentation at the meeting. The congress, sponsored by the International Water Supply Assn., will have a program consisting of six broad water supply topics in addition to disinfection (see September P&R, p. 56).

Harrell B. Rosson, formerly with Wallace & Tiernan Inc., has joined the Div. of Sanitary Engineering, State Dept. of Public Health, Nashville, Tenn., as principal sanitary engineer.

Engineers Joint Council announces the election of Augustus Kinzel, of Union Carbide Corp., as its new president. Cecil Boling, of Dunham-Bush, will be vice-president in 1960.

Chester A. Ring has been named to succeed the late Conrad W. O'Connell as superintendent and chief engineer of Plainfield-Union Water Co. in New Jersey. Ring was previously with American Water Works Service Co.

Harold V. Florence, retired superintendent of the Ridgewood (N.J.) Water Dept., died Nov. 17, 1959, at Hackensack, N.J. He was 63. Born in Brooklyn, N.Y., he had been associated with the department for 37 years prior to his retirement in 1957. He was a member of AWWA since 1953.

(Continued on page 50 P&R)

FLUIDICS* AT WORK

New Simplex telemeter reads and controls 2 to 29 channels

The new Orthoplex telemetering system uses a biplex generator and biplex selector to achieve dual signal telemetering using a single pair of telephone lines.

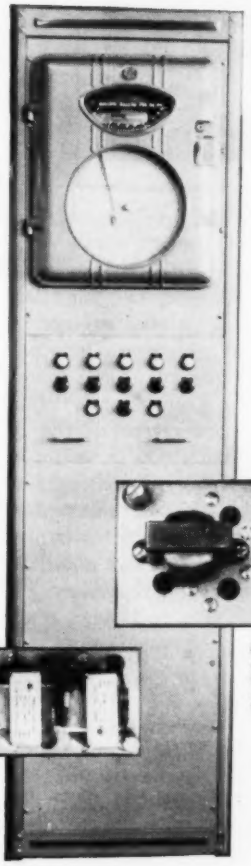
In the basic system the generator produces both a dc and a 60-cycle ac signal which is unscrambled at the receiving end by the selector. These 2 signals are fed into a multiplexing unit which provides the extra channels.

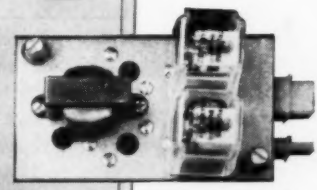
Uses ac and dc signals—Combining ac and dc currents produces a circuit less affected by line capacitance and able to give a longer distance transmission with available capacitance.

The new system requires much less maintenance than previous designs. It uses no vacuum tubes, eliminates all motorized timers and motorized sequence switches; and the modular units are equipped with "quick-disconnect" connectors, plug-in relays, and rectifiers of advanced design.

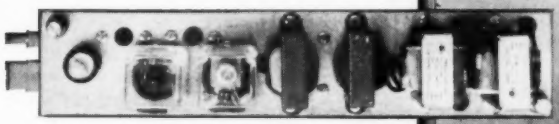
Modular design—The modular design allows building up as many as 29 separate channels for supervisory indicators, alarms, telemeter receivers, pump controls, valve positioners, etc.

For complete specifications and design theory, write for bulletin to our Simplex Division, Dept. AW-10, Lancaster, Pa.





BIPLEX Selector separates signals so they operate relays sensitive only to their assigned signal.



BIPLEX Generator is designed to give two signals, positive dc and 60-cycle ac.

SIMPLEX Orthoplex Supervisory Control provides you with a system for remote control of valves and pumps from a central station.

*FLUIDICS is a new Pfaudler Permutit program which provides a modern, imaginative approach for handling and processing liquids and gases more profitably.

SIMPLEX®
VALVE AND METER COMPANY
a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania
Specialists in FLUIDICS . . .
the science of fluid processes

(Continued from page 48 P&R)

W. Victor Weir, president and general manager, St. Louis County Water Co., died Nov. 19, 1959, at the age of 57. Born at Warren, Ind., in 1902, he received a B.S. in civil engineering in 1923 from Washington University in St. Louis. Beginning as an engineer with the West St. Louis County Water & Light Co. (predecessor of the St. Louis County Water Co.), he served as assistant manager, chief engineer, and supervisor, before becoming president in 1946. He subsequently became president and director of five additional water utilities—Missouri Water Co., Independence; Northern Illinois Water Co., Champaign; Illinois Water Service Co., Pontiac; Gary-Hobart Water Corp., Gary, Ind.; and Long Island Water Corp., Lynbrook, N.Y.

A member of AWWA since 1924, he became a Life Member in 1954 and an Honorary Member in 1956. He received the Diven Medal in 1940, the Fuller Award in 1943, and the Goodell Prize in 1950. He served the Association as director in 1946–49 and in 1952, vice-president in 1950, and president in 1951. He was also a member of ASCE, the Missouri Society of Professional Engineers, and the St. Louis Engineers Club.

Harold W. Griswold, consulting engineer, died Aug. 27, 1959, at Hartford, Conn. He was 72. Born in Hartford in 1886, he held a B.S. in civil engineering from Massachusetts Institute of Technology. Following service with the US Army Corps of Engineers, he joined the engineering staff of the Hartford Board of Water Commissioners in 1913. After this organization became the present Water Bureau of the Metropolitan District of Hartford, he continued as deputy manager and deputy chief engineer until his retirement in 1947.

A member of AWWA since 1933, he was also a member of ASCE, the Connecticut Society of Civil Engineers, and NEWWA, which he served as president in 1945–46.

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

WATER UTILITY MANAGER

Exceptional opportunity for man with experience in water utility operation. College degree and administrative ability essential. Will be responsible for all operations in his district, reporting to Vice-President. Location Chicago area. Send complete resume of experience to Box 9121A, Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

ENGINEERS AND DRAFTSMEN experienced in water supply, water distribution, sewerage or sewage treatment plant design. Salary commensurate with ability. Paid vacations, holidays, hospitalization. Address reply with resume to: O'Brien & Gere, Consulting Engineers, 400 East Genesee Street, Syracuse 2, New York.

Positions Wanted

Geologist, M.S., 25, single, training with major oil company, ground water experience, seeks position in ground water. Box 011W, Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

10° F
OUTSIDE...
boiling *at City Hall!*

Replacing frozen water meters? When temperatures drop, many a municipal official starts getting hot under the collar at the high cost of winter meter maintenance.

If you're among the men who stand for economy and efficiency in the water department, you have every right to be annoyed. Because there *is* a meter than can end these excessive expenses. That meter is called Calmet.

When water freezes in a Calmet, special shear pins allow its all-bronze, split case to separate. This protects both case and internal working parts. All your servicemen have to do is insert new shear pins—an operation that takes only a few minutes and costs practically nothing.

Unlike ordinary meters, a frozen Calmet seldom needs to be removed from the line. Unlike ordinary meters, it's almost impossible for freezing to damage a Calmet.

Keep cool: specify Calmet.

WORTHINGTON
CALMET METER DIVISION
2301 SO. MAIN
FORT WORTH, TEXAS

Service Lines

Meter boxes designed for outside reading and servicing are described in a 2-page bulletin. Information on the "Masterminder," which is available in two models developed primarily for homes without basements, may be obtained by writing the Handley-Brown Co., 2101 Brooklyn Rd., Jackson, Mich.

Recording instruments are classified and discussed in a 12-page, two-color booklet that includes photographs of all models described. Bulletin GEA-6933 is available from General Electric Co., Schenectady 5, N.Y.

Butterfly valve designs are presented in tabular form in a 4-page bulletin that features eight models. Valve sizes range from 1 in. to 108 in., with pressure drops up to 1,200 psi and temperatures up to 2,000°F. To get a copy of Bulletin 50-1, write to Continental Equipment Co., Coraopolis, Pa.

Clarifiers are the subject of a 6-page brochure that contains drawings and data on several models. Bulletin WC-123 may be obtained from Graver Water Conditioning Co., 216 W. 14th St., New York 11, N.Y.

Lime slaking is discussed in a 4-page, illustrated bulletin that explains the design and operational features of newly developed equipment. Bulletin 40-RI is available from B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R.I.

for Public Water Fluoridation

Sodium Silicofluoride – 99%
(Powder)

Sodium Fluoride – 98%
(Powder or Granular)

Meet AWWA specifications

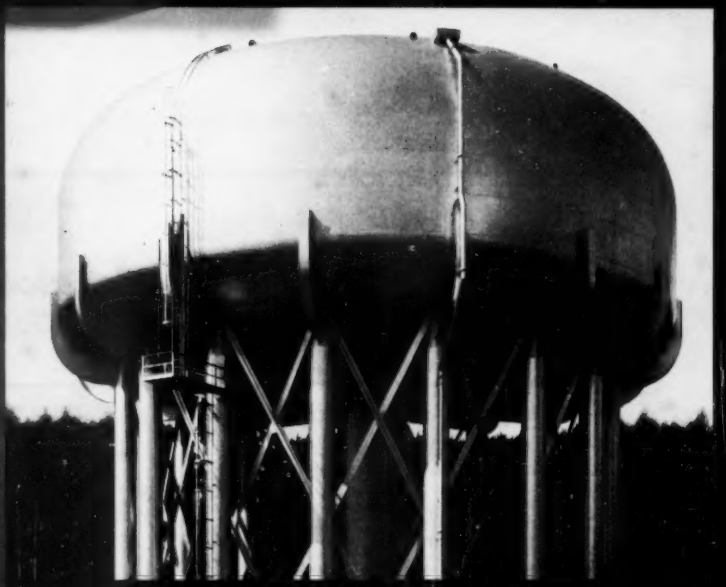
White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY
100 Church Street, New York 7, N. Y.

AA QUALITY

PDM
ELEVATED STEEL TANKS

ELEVATED STEEL TANKS



Radial cone tank, Seattle, Wash. Capacity 2,000,000 gallons.

FIRST IN EXCELLENCE

TO SERVE DEPENDABLY THE WATER STORAGE NEEDS OF MODERN AMERICAN COMMUNITIES

Pittsburgh-Des Moines

From the first PDM Elevated Steel Tank, pioneered in 1897, to the handsome structures of the present, *first quality* has been our continually-realized objective. You'll find in the wide range of PDM tank types and capacities the ideal unit for your requirements—guaranteed in performance and satisfaction. Let us submit a quotation.

Toro-segmental tank, Sioux City, Ia. Capacity 2,000,000 gallons.

Radial cone tank, Independence, Kansas. Capacity 750,000 gallons.

Double-ellipsoidal tank, Melbourne, Fla. Capacity 300,000 gallons.

Pedestal sphere, Hawthorne, Calif. Capacity 250,000 gallons.

WRITE FOR this fully-illustrated 28-page "Modern Water Storage" brochure—detailing the range of PDM Elevated Steel Tanks. Free on request to our nearest office.

Pittsburgh-Des Moines Steel Company

Plants at Pittsburgh, Warren, Bristol, Pa. • Baltimore • Birmingham • Des Moines • Provo, Utah • Casper, Wyo. • Santa Clara, Fresno, Stockton, Calif.

Sales Offices:

PITTSBURGH (25) . . . . 3424 Neville Island
BALTIMORE (26) . . . . . Curtis Bay Station
NEW YORK (17) Suite 2721, 200 E. 42d St.
CHICAGO (3) . . 628 First Nat'l Bank Bldg.
ATLANTA (5) . . 361 E. Paces Ferry Rd., N.E.
JACKSONVILLE . . . . . 1757 River Road
DES MOINES (8) . . . . . 925 Tuttle Street
DENVER (2) 323 Railway Exchange Bldg.
DALLAS (1) Suite 1729, Southland Center
SEATTLE (1) . . . . Suite 332, 500 Wall St.
SANTA CLARA, CAL. . . . 631 Alviso Road
EL MONTE, CAL. . . . . P. O. Box 2012

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

Three Penn Center Plaza Philadelphia 2, Pa.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

AWWA STANDARDS

for Water Works Materials

Compiled, approved and published by your Association to meet your needs.

Send for list of publications.

American Water Works Association, Inc.
2 Park Avenue New York 16, N.Y.

AYRES, LEWIS, NORRIS & MAY

Consulting Engineers

LOUIS E. AYRES — ROBERT NORRIS
GEORGE E. LEWIS — DONALD C. MAY
STUART B. MAYNARD — HOMER J. HAYWARD

Waterworks, Sewerage, Electric Power

500 Wolverine Building, Ann Arbor, Michigan

BLACK & VEATCH

Consulting Engineers

1500 Meadow Lake Parkway, Kansas City 14, Missouri

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports

BLACK AND ASSOCIATES, INC.
BLACK LABORATORIES, INC.

Engineers and Chemists

Water, Sewerage, Hydrology, Waste Treatment
Complete Laboratory Services

700 S. E. 3rd St. Gainesville, Fla.

CLINTON BOGERT ENGINEERS

Consultants

CLINTON L. BOGERT — IVAN L. BOGERT
DONALD M. DITMARS — ROBERT A. LINCOLN
CHARLES A. MANGANARO — WILLIAM MARTIN

Water & Sewage Works — Incinerators
Drainage — Flood Control
Highways and Bridges — Airfields

145 East 32nd Street, New York 16, N. Y.

Bowe, Albertson & Associates

Engineers

Water and Sewage Works
Industrial Wastes
Refuse Disposal
Valuations
Laboratory Service

75 West Street New York 6, N.Y.
1000 Farmington Ave. West Hartford 7, Conn.

Brockway, Weber & Brockway

Engineers, Incorporated

George S. Brockway Roy E. Weber
George R. Brockway

Staff

H. L. Fitzgerald — Charles A. Anderson
Robert E. Owen — Ben E. Whittington
Thomas A. Clark — Ernest L. Greene
Thomas R. Demery

Civil, Structural, Sanitary, Municipal, Electrical, Land Planning

West Palm Beach, Florida Ft. Pierce, Florida

BROWN AND CALDWELL

Civil and Chemical Engineers

Water—Sewage—Industrial Waste
Consultation—Design—Operation
Chemical and Bacteriological Laboratories

66 Mint Street San Francisco 3

Professional Services

BUCK, SEIFERT AND JOST
Consulting Engineers

WATER SUPPLY—SEWAGE DISPOSAL—HYDRAULIC DEVELOPMENTS

Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management, Chemical and Biological Laboratories

112 E. 19th St., New York 3, N. Y.

BURGESS & NIPLE
Consulting Engineers

(Established 1908)

Water Supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Laboratory Municipal engineering
Supervision

2015 W. Fifth Ave. Columbus 12, Ohio

THE CHESTER ENGINEERS

Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants—Incineration—Gas Systems
Valuations—Rates—Management
Laboratory—City Planning

601 Suismon Street
Pittsburgh 12, Penna.

BURNS & McDONNELL
Engineers—Architects—Consultants

4600 E. 63rd St. Trafficway
Kansas City 41, Missouri

CHAS. W. COLE & SON
Engineers and Architects

3600 E. Jefferson Blvd. South Bend, Indiana
2112 W. Jefferson St. Joliet, Illinois

JAMES M. CAIRD

Established 1898

C. E. CLIFTON, H. A. BENNETT

Chemist and Bacteriologist

WATER ANALYSIS
TESTS OF FILTER PLANTS

Cannon Bldg. Troy, N. Y.

CONSOER, TOWNSEND & ASSOCIATES
Consulting Engineers

Sewage treatment, sewers, storm drainage, flood control — Water supply and treatment — Highway and bridges—Airports—Urban renewal—Electric and gas transmisson lines — Rate studies, surveys and valuations — Industrial and institutional buildings.

360 East Grand Avenue Chicago 11, Illinois

CAMP, DRESSER & McKEE
Consulting Engineers

Water Works, Water Treatment,
Sewerage and Wastes Disposal,
Flood Control

Investigations, Reports, Design
Supervision, Research, Development

6 Beacon St. Boston 8, Mass.

DAY & ZIMMERMANN, INC.
Consulting Engineers

Valuations
Feasibility Studies & Reports
Rate Cases & Financial Studies
Supervisory Consulting Service

1700 Sansom St. Philadelphia 3, Pa.

CAPITOL ENGINEERING CORP.
Consulting Engineers

WATER WORKS—SEWAGE DISPOSAL—AIRPORTS—DAMS—BRIDGES—ROADS AND STREETS

Investigations, Reports, Appraisals, Rates, Survey and Design, Construction Supervision

Dillsburg, Pa.
Rochester, N. Y. Washington, D.C.

Fay, Spofford & Thorndike, Inc.
Engineers

Water Supply and Distribution — Drainage
Sewerage and Sewage Treatment—Incinerators
Airports — Bridges — Express Highways

Investigations Reports Valuations
Designs Supervision of Construction

11 Beacon St., Boston 8, Massachusetts

Professional Services

FINKBEINER, PETTIS & STROUT

Consulting Engineers

Water Supply, Water Treatment,
Sewerage, Sewage Treatment,
Bridges, Highways & Expressways

2130 Madison Avenue — Toledo 2, Ohio

GREELEY AND HANSEN

Engineers

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

14 E. Jackson Blvd., Chicago 4

FREESE, NICHOLS & ENDRESS

Consulting Engineers

407 Danciger Building
Fort Worth, Texas

GROUND WATER ASSOCIATES

Consulting Hydrologists and Engineers

Investigations, Reports and Recommendations on Underground Water Supplies. Preparation of Plans and Specifications.

Box 480 — JEfferson 6-0494
Norman, Oklahoma

FROMHERZ ENGINEERS

Structural—Civil—Municipal
Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Highways & Streets
Investigations; Reports; Plans and Specifications; Supervision

New Orleans

WILLIAM F. GUYTON & ASSOCIATES

Consulting Ground-Water Hydrologists

Underground Water Supplies
Investigations, Reports, Advice

307 W. 12th St.
Austin 1, Texas
Phone: GR-7-7165

GANNETT FLEMING CORDDRY & CARPENTER, Inc.

Engineers

Water Works—Sewerage
Industrial Wastes—Garbage Disposal
Roads—Airports—Bridges—Flood Control
Town Planning—Appraisals
Investigations & Reports

Harrisburg, Pa. — Philadelphia, Pa.
Pittsburgh, Pa. — Daytona Beach, Fla.

HASKINS, RIDDLE & SHARP

Consulting Engineers

Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction, Appraisals, Valuations, Rate Studies

1009 Baltimore Avenue — Kansas City 5, Mo.

GET YOUR COPY NOW!

A list of AWWA books, manuals, standards, and other publications may be had for the asking. Is your library complete?

American Water Works Association, Inc.
2 Park Avenue — New York 16, N.Y.

HAVENS & EMERSON

A. A. Burger — H. H. Moseley
J. W. Avery — F. S. Palocsay
E. S. Ordway — G. H. Abplanalp
A. M. Mock — S. H. Sutton
F. C. Tolles, Consultant

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations—Laboratories

Leader Bldg. CLEVELAND 14 — Woolworth Bldg. NEW YORK 7

Professional Services

HAZEN AND SAWYER
Engineers
Richard Hazen Alfred W. Sawyer
H. E. Hudson, Jr.

Water and Sewage Works
Industrial Waste Disposal
Drainage and Flood Control

360 Lexington Ave. New York 17, N.Y.

THE JENNINGS-LAWRENCE CO.
Civil & Municipal Engineers
Consultants

Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction

1392 King Avenue Columbus 12, Ohio

ANGUS D. HENDERSON
Consulting Engineers
Angus D. Henderson Thomas J. Casey

Water Supply and Sanitation

330 Winthrop St. Westbury, New York
210-07—29th Ave. Bayside, New York

JONES, HENRY & WILLIAMS
Consulting Sanitary Engineers

Water Works
Sewerage & Treatment
Waste Disposal

2000 West Central Avenue Toledo 6, Ohio

H. G. Holzmacher & Associates
Consulting Engineers
H. G. Holzmacher
R. G. Holzmacher S. C. McLendon

Municipal Engineering
Water Supply & Treatment
Sewerage & Treatment
Water Analysis Laboratory

66 W. Marie Street, Hicksville, L. I., New York

HARRY J. KEELING
Consulting Engineer
Electrical—Mechanical—Corrosion

Investigations—Reports—Advisory Service
Mobile radio communication systems;
Special mechanical design problems;
Soil corrosion, Electrolysis,
Cathodic protection
of buried or submerged metal surfaces.

1780 S. Robertson Blvd. Los Angeles 35, Calif.

HORNER & SHIFRIN
Consulting Engineers
E. E. Bloss V. C. Lischer

Airports, Sewerage & Drainage, Hydrology, Sewage & Industrial Waste Treatment, Water Supply & Treatment, Paving, Structures, Industry Engineering Services

1221 Locust Street St. Louis 3, Mo.

KENNEDY ENGINEERS
Richard R. Kennedy Robert M. Kennedy

Investigation—Design
Water Supply Water Purification
Sewage and Waste Treatment
Water Reclamation

604 Mission St., San Francisco 5
Tacoma Los Angeles Salt Lake City

ROBERT W. HUNT CO.
Inspection Engineers
(Established 1888)

Inspection and Test at Point
of Origin of Pumps, Tanks,
Conduit, Pipe and Accessories

810 S. Clinton St.
Chicago 7, Ill.
and Principal Mfg. Centers

DEAN S. KINGMAN
Consulting Engineer

Water Works
Sewerage & Treatment

153 University Avenue
Palo Alto, California

Professional Services

MORRIS KNOWLES INC.

Engineers

Water Supply and Purification,
Sewerage and Sewage Disposal,
Industrial Wastes, Valuations,
Laboratory, City Planning

Park Building **Pittsburgh 22, Pa.**

METCALF & EDDY

Engineers

Water, Sewage, Drainage, Refuse
and Industrial Wastes Problems
Airports Valuations
Laboratory

Statler Building
Boston 16

KOEBIG & KOEBIG

Consulting Engineers Since 1910

Investigations, Reports, Designs
Water Supply & Water Treatment
Sewerage & Sewage Treatment
Municipal Engineering

3242 W. Eighth St. **Los Angeles 5, Calif.**

JAMES M. MONTGOMERY

Consulting Engineer

Water Supply—Water Purification
Sewerage—Sewage and Waste Treatment
Flood Control—Drainage
Valuations—Rates
Investigations—Design—Operation

535 E. Walnut St. **Pasadena, Calif.**

R. E. LAYTON & ASSOCIATES

Consulting Engineers

Water Supply—Water Purification &
Distribution
Waste Water Disposal
Water Power—Hydraulic Structures
Small Craft Harbors
Investigations—Reports—Design
Construction Plans & Specifications

655 West Avenue 135th
San Leandro, California

Nussbaumer, Clarke & Velzy, Inc.

Consulting Engineers

Sewage Treatment—Water Supply
Incineration—Drainage
Industrial Waste Treatment
Appraisals

327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

LEGGETTE, BRASHEARS & GRAHAM

Consulting Ground Water Geologists

Water Supply — Salt Water Problems
Dewatering — Investigations
Recharging — Reports

551 Fifth Avenue **New York 17, N. Y.**

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS

Civil and Sanitary Engineers

Water, Sewage, Drainage and
Industrial Waste Problems.

Structures — Power — Transportation

165 Broadway **New York 6, N. Y.**

Look to the Journal Advertising Pages

for guidance when you require professional services or water works products. A "Buyers' Guide" appears in the final pages of this issue.

American Water Works Association, Inc.
2 Park Avenue **New York 16, N. Y.**

MALCOLM PIRNIE ENGINEERS

Civil & Sanitary Engineers

MALCOLM PIRNIE ERNEST W. WHITLOCK
ROBERT D. MITCHELL CARL A. ARENANDER
MALCOLM PIRNIE, JR.

Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates

25 W. 43rd St. **New York 36, N. Y.**

Professional Services

THE PITOMETER ASSOCIATES, INC.

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement & Special Hydraulic Investigations

50 Church Street **New York**

RIPPLE & HOWE, INC.

Consulting Engineers

V. A. Vaseen **B. V. Howe**

Appraisals—Reports
Design—Supervision

Water Works Systems, Filtration and Softening Plants, Reservoirs, and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports

833—23rd St., Denver 5, Colo.

Professional Cards in the 1960 AWWA MEMBERSHIP DIRECTORY

A must for water supply consultants

Reserve your space now

American Water Works Association, Inc.
2 Park Avenue **New York 16, N.Y.**

ROBERT AND COMPANY ASSOCIATES

Engineering Division

Power Plants — Water Sewage Plants
Airports — Industrial Plants
Docks and Terminal Facilities
Reports — Investigations

96 Poplar Street, Atlanta, Georgia

LEE T. PURCELL

Consulting Engineer

Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation

Analytical Laboratories

36 De Grasse St. **Paterson 1, N. J.**

RUSSELL & AXON

Consulting Engineers

Civil—Sanitary—Structural
Industrial—Electrical
Rate Investigations

408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

RADER AND ASSOCIATES

Engineers and Architects

Water Supply, Treatment and Distribution
Sewers and Sewage Treatment
Investigations, Reports, Plans
Supervision of Construction and Operations
Aerial Photography, Photogrammetry

The First National Bank Building, Miami 32, Florida
1025 Connecticut Ave. N. W. Washington 6, D. C.

J. HOMER SANFORD

Consulting Engineer—Hydrologist

39 Years of Groundwater Investigation

Groundwater Development, Recharge, Dewatering and Salt Intrusion
Analysis of Available Supply and Safe Yield
Litigation Reports and Testimony

1143 E. Jersey Street **Elizabeth 4, N. J.**

THOMAS M. RIDDICK & ASSOCIATES

Consulting Engineers and Chemists

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses

369 E. 149th St. **New York 55, N.Y.**
MOtt Haven 5-2424

SERVIS, VAN DOREN & HAZARD

Engineers—Architects

Investigations · Design · Supervision of Construction · Appraisals

Water · Sewage · Streets · Expressways · Highways · Bridges · Foundations · Airports · Flood Control · Drainage · Aerial Surveys · Site Planning · Urban Subdivisions · Industrial Facilities
Electrical · Mechanical

2910 Topeka Blvd. **Topeka, Kansas**

J. E. SIRRINE COMPANY

Engineers
Since 1902
GREENVILLE, SOUTH CAROLINA

Design, Reports, Consultations
Water Supply and Treatment
Sewage and Industrial Waste Treatment
Stream Pollution Surveys

R. KENNETH WEEKS

ENGINEERS
Designers • ***Consultants***

Water Supply and Purification
Sewerage and Sewage Treatment
Investigations and Reports
Supervision of Construction

Streets and Highways

6165 E. Sewells Point Road, Norfolk 13, Va.

SMITH AND GILLESPIE

Consulting Engineers

MUNICIPAL UTILITIES
AND PUBLIC WORKS

Complete Engineering Services

JACKSONVILLE, FLORIDA

ROY F. WESTON, INC.

Engineers—Biologists—Chemists

Water—Sewage—Industrial Wastes
Stream pollution—Air pollution

Surveys—Research—Development—Process Engineering—Plans and Specifications—Operation Supervision—Analyses—Evaluations and Reports

Newtown Square, Pa.

STANLEY ENGINEERING COMPANY

Consulting Engineers

Hershey Building **208 S. LaSalle St.**
Muscatine, Ia. **Chicago 4, Ill.**

1154 Hanna Building
Cleveland 15, Ohio

WESTON & SAMPSON

Consulting Engineers

Water Supply and Purification; Sewerage, Sewage and Industrial Wastes Treatment. Reports, Designs, Supervision of Construction and Operation; Valuations. Chemical and Bacteriological Analyses

14 Beacon Street **Boston 8, Mass.**

ALDEN E. STILSON & ASSOCIATES

(Limited)
Consulting Engineers

Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports

245 N. High St. **75 Public Square**
Columbus, Ohio **Cleveland 13, Ohio**

WHITMAN & HOWARD

Engineers
(Est. 1869)

Investigations, Designs, Estimates, Reports, Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 Broad St. **Boston, Mass.**

WATER SERVICE LABORATORIES, INC.

Chemical Engineers

Specialists in Water Treatment
Consulting and Technical Services

Main Office: 615 W. 131 St., N. Y. 27, N. Y.
Offices also in: Phila., Wash., & Richmond

WHITMAN, REQUARDT & ASSOCIATES

Engineers ***Consultants***

Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans
Supervision, Appraisals

1304 St. Paul St. **Baltimore 2, Md.**

J. STEPHEN WATKINS

J. S. Watkins G. R. Watkins
Consulting Engineers

Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.

446 East High Street **Lexington, Kentucky**
Branch Offices
5402 Preston Highway, Louisville 13, Kentucky
107 Hale Street, Charleston, W. Va.

WILSEY & HAM

Engineers

Investigation and Design
Water Supply, Treatment and Distribution
Sewage Treatment and Disposal
Airports, Municipal Works and City Planning

111 Rollins Road **800 W. Colorado Blvd.**
Millbrae, California **Los Angeles 41, Calif.**

New steels are born at Armco
ENGLEWOOD BUILDS
WATER TRANSMISSION CONDUIT
BIRCHBY E. NAUMAN INC.
845 NAVAJO ST. DENVER, COLO.

Armco Welded Steel Pipe Solves A Problem in Englewood

When Englewood, Colorado, needed a transmission line to pump water from the filter plant to an elevated storage reservoir, city officials specified Armco Welded Steel Pipe. The 12,000-foot line crosses several streets and passes through some rough terrain. Armco Pipe was selected because of its economy and ease of installation.

Armco Steel Pipe can make short work of *your* water transmission problems, too. Linings and coatings are supplied according to AWWA Standard C-203. You choose from diameters of 6 to 36 inches and wall thicknesses from 9/64- to ½-inch. Write us for complete information. Armco Drainage & Metal Products, Inc., 4140 Curtis Street, Middletown, Ohio.

ARMCO DRAINAGE & METAL PRODUCTS

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation

Condensation

Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

HEALTH AND HYGIENE

Effect of Water With a High Fluorine Content on Health of Adult Population. V. KNIJHNIKOV. *Hyg. & Sanit.* (USSR), 23:8:18 (Aug. '58). In Schuchinsk, water supply contains 4 ppm of fluorine, and in Kokchetav 0.09 ppm. Clinical and lab. examinations of 222 adult inhabitants of these towns and a statistical study of the mortality and morbility rates indicated that no disorders, other than mottled enamel of teeth, could be associated with presence of fluorine in water. It is therefore concluded that presence of fluorine in water in concns. not exceeding 4 ppm is not detrimental to public health.—*WPA*

Experimental Study of the Combined Action of Fluorine and Calcium in Drinking Water. G. N. KRASOVSKY. *Hyg. & Sanit.* (USSR), 23:3:30 (Mar. '58). Expts. with white rats and mice as test animals indicated that administration of calcium, even in doses sufficient to saturate organism, had no positive effect on survival of animals suffering from acute poisoning due to large amts. of sodium fluoride. During chronic poisoning of rats by fluorides in drinking water, addn. of very high concns. of calcium to water delayed and slightly reduced changes in teeth. Chronic poisoning expts. using radioactive phosphorus-32 and calcium-45 as tracers, showed that rate of penetration of phosphorus and calcium into skeletal system and soft tissues was similar whether fluorides were given with calcium or independently. Changes in rate of excretion of radioactive iodine-131 in urine of rats due to a high content of fluorine in drinking water could not be prevented by addn. of excess calcium to water. It is, therefore, concluded that calcium, even in large doses, has no protective effect on exptl. animals receiving fluorine in drinking water.—*WPA*

Some Data on the Hygienic Significance of Nitrates in Drinking Water. F. N. SUBBOTIN. *Hyg. & Sanit.* (USSR), 23:3:27 (Mar. '58). A series of investigations is described in which children at nursery were given water from public supply system, which was free from nitrates, and children at another nursery were given well water containing 8, 20, or 30 mg/l nitrate. Ages of children ranged from 2 mo to 4 yr. At 1st nursery there were 64 children and blood of 25 children was found to contain methaemoglobin; methaemoglobin content, however, only exceeded 5% in 6 cases. At 2nd nursery, 49 children received well water containing 20 or 30 mg/l nitrate and 10 children well water containing 8 mg/l nitrate; blood of 47 children contained methaemoglobin and in 26 cases amt. exceeded 5%; no methaemoglobin was found in blood of children given water containing 8 mg/l nitrate. It is concluded that nitrate content of drinking water must be determined; it should not exceed 10 mg/l.—*WPA*

Investigations for the Determination of the Hygienic Concentration Standard of Chlorides and the Chloride-Sulfate Complex in Drinking Water. I. A. MALEVSKAYA. *Hyg. & Sanit.* (USSR), 23:4:11 (Apr. '58). Author introduced small concns. of chlorides (0.25–8.0 g/l) and chlorides and sulfates mixed in different proportions (tot. amt. 1.0 and 1.5 g/l) in water into stomach of a dog and found secretion of gastric juices was inhibited when water contained 0.5 g/l or more of chlorides. It has been observed that persons with an artificially induced state of thirst drink different amts. of water depending on its quality. Investigations were carried out on 200 people who had been drinking water with an avg. mineral content (up to 300 mg/l) or with a high mineral content (2,522–3,314 mg/l) and from results

(Continued on page 64 P&R)

a name to remember...

HALLIBURTON

FOR WATER WELL SERVICE REQUIREMENTS!

Whatever the service requirements of your water well, you can depend on Halliburton for the services and tools that are engineered to increase the life and yield of your reservoir. Halliburton, world leader in well techniques and equipment, offers the following services:

CEMENTING . . . For maximum protection of natural permeability and porosity of the producing formation and casing; minimized migration of fluid.

FRACTURING AND ACIDIZING . . . Effective application of propping agents and chemicals for stimulation and increased yield, by enlargement of flow channels or removal of restrictions.

HYDRO-SONIC REDEVELOPMENT . . . A proven technique that provides fast, efficient and economical treatment of water supply wells by means of controlled sonic shock waves and high frequency bubble agitation.

FORMATION TESTING . . . Tools and techniques specifically designed for more accurate reservoir evaluation . . . for evaluating potential.

SALES PRODUCTS AND MATERIALS . . . Halliburton offers a wide variety of field-tested, well-proven tools and materials developed to help make your water well a profitable producer.

Whatever the type of your water well . . . potable, irrigation or industrial supply . . . whatever the nature of your well's service requirements, you can rely on Halliburton for outstanding service There are 284 Service Camps ready to serve you.

For the Service Camp address nearest you, write or call . . .

HALLIBURTON OIL WELL CEMENTING COMPANY

DUNCAN, OKLAHOMA

(*Continued from page 62 P&R*)

it is suggested that max. permissible concn. of chlorides in drinking water should be 500 mg/l.—*WPA*

Hygienic Evaluation of Formaldehyde as a Factor of Pollution of Reservoirs. I. V. NAZARENKO. *Hyg. & Sanit.* (USSR), 23: 1:3 (Jan. '58). Effect of formaldehyde on hygienic and organoleptic quality of water in reservoirs and on warm-blooded animals has been investigated. Results are shown diagrammatically and in tables, and on basis of these observations it is recommended that max. permissible concentration of formaldehyde in water should be fixed at 0.5 mg/l. —*WPA*

An Epidemic of Enteritis Laid to Cross Connection. F. MILLER & B. FREEDMAN. *Pub. Health Repts.*, 73:658 ('58). An incident in Shreveport, La., which led to an outbreak of enteritis, is described. Water for lawn sprinkling was first of all taken from a region named Bayou Pierre, but was later obtained also from public water supply. Sewage leaked into bayou from a fault in sewerage system, and drained into public water supply, because old lawn-sprinkling system had not been disconnected from public water supply. Details of outbreak, and an analysis of cases, with a graph of their occurrence are given, together with a map of region in which epidemic occurred. Recommendations are made that all lawn-sprinkling systems should be registered, and that regulations for the installation of water supply and plumbing systems should be strictly observed.—*WPA*

Chemical and Bacteriological Investigations of Ground Water During an Epidemic of Hepatitis. G. WEBER. *Oesterr. Wasserwirtsch.* (Vienna), 10:110 ('58). In a district where well water was used, sewage from 80 persons was disposed of by mechanical treatment followed by seepage. Wells in neighborhood were examined before seepage began; some were found to be faulty in construction, bacteriological results were sometimes unsatisfactory, but chemically there was no evidence of serious poln. Examination 6 mo. after seepage began showed definite deterioration in chemical condition of water. Color tests showed that color reached one well in one day, another in 3 days, and a third in a month. Use of first well had been given up when seepage began. Epidemic hepatitis broke out in other 2 houses. As color took 1 mo to reach third house and probably travelled faster than virus, it appears that hepatitis virus can remain infectious in ground water for considerable periods. Chemical analysis gave clear evidence of poln.; results are given and effects on contents of iron, nitrate, chloride, ammonium, and alkali bicarbonates are discussed. Sensitivity of bicarbonate test for fecally polluted waters and danger of using seepage of sewage to supplement ground water for drinking purposes are emphasized. —*WPA*

Copper Poisoning From Vending Machines. S. HOPPER & H. ADAMS. *Pub. Health Repts.*, 73:910 ('58). This paper contains a description of some investigations which were undertaken to det. amts. of copper which might appear in carbonated drinks provided by certain vending machines. A no. of cases of acute gastric upset "that appear to be copper poisoning" had been reported in persons who had consumed drinks from these machines. These vending machines release 1 oz of flavored syrup into a cup and then add 5 oz or more of carbonated water. Some cases of alleged copper poisoning are described and toxicity of copper is discussed with reference to published opinions on this matter which are by no means unanimous. Some expts. on amts. of copper found in water contained in a copper tube after different periods of exposure to carbon dioxide under pressure or at varying hydrogen-ion concns. are described. In conclusion it is stated that if check valves in a postmix vending machine do not function correctly, carbon dioxide may enter water supply line. If this water line is made of copper, CO_2 or carbonated water will react with copper and, under certain conditions, copper going into soln. could be quite large. Copper poisoning could then occur and, although this poisoning has occurred in only very few persons, it could be prevented by attention to certain technical points in construction of machines.—*BH*

Hygiene of Central Water Supply Plants in Rural Districts (Austria). K. BRAUN. *Oesterr. Wasserwirtsch.*, 10:98 ('58). Author discusses tech., hygienic, economic, and financial difficulties of water supply in rural

(*Continued on page 68 P&R*)

RED WATER?
TURBIDITY?
Eliminate these problems with GFC Aerators and Filters

Iron and corrosive, odorous gases cause red water, leaky pipes and clogged meters. Unless corrected, these problems will result in loss of revenue, and consumer complaints.

GFC Forced Draft Aerators and Filters can solve these problems. They are designed for easy assembly, dependability and long life.

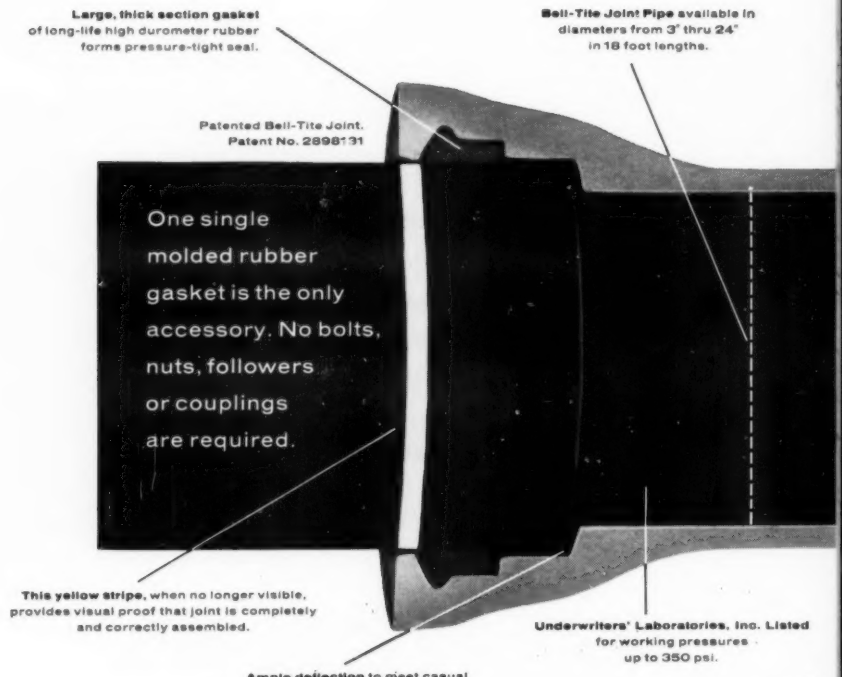
Ask about our new aluminum and fiberglas Aerators. Write for your copy of our new Aerator and Filter Plant bulletins with design data and problem analyses.

GENERAL FILTER CO.
WATER PROCESS EQUIPMENT AMES, IOWA

AERATORS • FILTERS • SOFTENERS • CLARIFIERS
FLASH MIXERS • FLOCCULATORS • PNEUMATIC CONTROLS
ROTARY DISTRIBUTORS • SLUDGE SCRAPERS

CLOW

Quick, Bottle-Tight Seal


Large, thick section gasket of long-life high durometer rubber forms pressure-tight seal.
Bell-Tite Joint Pipe available in diameters from 3" thru 24" in 18 foot lengths.
Patented Bell-Tite Joint. Patent No. 2898131
One single molded rubber gasket is the only accessory. No bolts, nuts, followers or couplings are required.
This yellow stripe, when no longer visible, provides visual proof that joint is completely and correctly assembled.
Underwriters' Laboratories, Inc. Listed for working pressures up to 350 psi.
Ample deflection to meet casual curves or grades is provided by space in socket of the bell.

CLOW CAST IRON PIPE

Cast Iron Pipe Plants at

SENSENVILLE, ILLINOIS • BIRMINGHAM, ALABAMA • COSHOCTON, OHIO

CAST IRON PIPE

You can install

CLOW BELL-TITE® JOINT PIPE

as fast as you can dig a shallow trench

Pictures show CLOW 20" Bell-Tite Joint Cast Iron Pipe being installed to provide water for a midwestern industrial development. CLOW Bell-Tite Joint Cast Iron Pipe was selected because of its proved long life and the ease and speed of installation. Hulett Corporation, contractors.

LOWER pipe into trench

SWING into open bell

SEAL for pressure-tight joint

JAMES B. CLOW & SONS, INC.
201-299 North Talman Avenue, Chicago 80, Illinois

Subsidiaries:
Eddy Valve Company
Waterford, N.Y.
Iowa Valve Company
Oskaloosa, Iowa

(Continued from page 64 P&R)

areas and advantages of group water supplies. Brief accounts are given of 2 group supplies in Burgenland. He then describes testing of a ground water stream near river Leitha. Effect of increase and decrease in flow of river and rate of horizontal filtration were examined. Tests of ground water in neighborhood of L. Neufeld, an artificial lake formed in exhausted minefields, are described.—*WPA*

Water Supply and Hygienic Precautions During Flooding. F. SCHULZ. *Oesterr. Wasserwirtsch.* (Vienna), 10:104 ('58). Author describes, from experiences during flooding in 1956, precautions necessary to avoid outbreaks of disease when water supplies are affected or cut off by floods. Advantage of having a possible alternative supply, action to be taken to warn public when wells have been pold. by flood water, precautions necessary in evacuation centers when popn. has to be removed, and cleaning of wells and ground when flood has receded, are discussed.—*WPA*

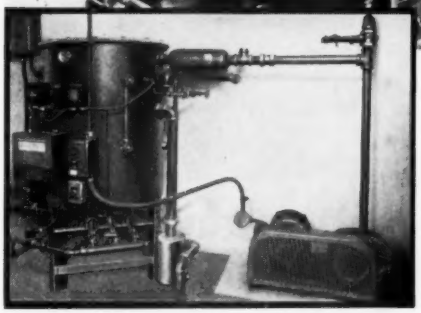
Are Water Pipes of Synthetic Materials Permeable to Gas? G. C. VIETEN. *Ztg. Kommun. Wirtsch.*, 41:4 ('57); *Zbl. Bakt., I, Ref.*, 167:111 ('58). In some places in Holland where pipes of synthetic materials are used for water, odor and taste of gas have been observed in water. Investigation showed that odor occurred with polyethylene but not with polyvinylchloride pipes. Other investigations showed that increased bact. growth occurred in synthetic pipes as compared with lead pipes; this growth was, however, hygienically harmless. It is possible that growth of bacteria in very long pipes might lead to an excessive oxygen demand. It is also possible that certain industries—for example, dairies, which require a high bact. quality in their water—might have difficulties in use of synthetic pipes.—*WPA*

How Are Pipes and Fittings of Synthetic Materials to be Judged From the Point of View of Water Hygiene? W. AHRENS. *Wasserwirtsch. & Wassertechnol.*, 7:348 ('57); *Zbl. Bakt., I, Ref.*, 167:111 ('58). Pieces of polyamide material, sterilized in steam bath or autoclave, were placed in glass vessels with normal and dechlorinated tap water with a low bact. content. Tot. bact. count increased in 5 days to values of 1,000,000 per ml, increase being considerably more rapid in dechlorinated than in normal tap water. In a distilled water with a chlorine content of 12 mg/l, retention in a polyamide beaker reduced chlorine in 2 days to 1.2 mg/l; a similar sample in a glass vessel still contained 9.8 mg/l. Author gives warning against underestmg. hygienic importance of these results. Observations suggest that increase in bact. nos. disappears after about 6 mo with washing out of nutrient material from pipes. Further expts. were made by adding pieces of polyamide material to chlorinated and dechlorinated tap water infected with typhoid bacteria. In chlorinated water bacteria were no longer detectable in 1 ml after 24 hr, but in dechlorinated water they had increased in 24 hr from about 5,000 to about 7,000/ml; they were still detectable after 5 days. Author points out that his results are too few to rule out element of chance.—*WPA*

Investigations on the Behavior of Pipes of Synthetic Materials in Water Distribution Systems. W. SCHWARTZ & A. MULLER. *Wasserwirtsch. Wassertechnol.*, 7:S8 ('57); *Zbl. Bakt., I, Ref.*, 167:112 ('58). Authors describe expts. made with stagnant and flowing water in pipes of various synthetic materials. Copper pipe was used as control. At beginning of the expts. there was an increase of bact. nos. which was, however, temporary. Flowing water in both exptl. and control pipes showed little or no increase in bact. nos. Stagnant water in pipes show a bact. increase regardless of material of pipes.—*WPA*

Use of Pipes of Synthetic Materials in Water Supply Systems. A. MULLER & W. SCHWARTZ. *Kunststoffe*, 47:583 ('57); *Zbl. Bakt., I., Ref.*, 167:112 ('58). Expts. are described in which flasks, containing nutrient material and either no sources of organic carbon or synthetic pipe materials or paraffin, were inoculated with cultures of bacteria known to have a corroding action on synthetic materials. All tests showed in 1st wk a considerable increase in bact. nos., which was maintained for 168 days of expt. Expts. with pipes of synthetic materials showed that bacteria increased in water stagnating in pipes but increase disappeared when water flowed through pipes. Though bact. increase can thus be ascribed to stagnation and not

(Continued on page 70 P&R)



Four size 4 Carballs at Kansas City, Mo. burn either gas or oil to produce max. of 40,000 lbs. CO_2/day. Size "O" unit at left produces 570 lbs. CO_2/day for Jefferson, Iowa Water Plant.

CARBALL
CO_2 UNIT

Walker Process now offers carbonation units for all lime softening plants from the very small to the largest. Sizes range from the new "OO" unit with minimum capacity of 55 lbs. CO_2/day to the No. 4 at maximum output of 10,000 lbs. CO_2/day.

Engineers can readily provide an entire carbonation system by simply specifying the appropriate size CARBALL in combination with Walker Process SPARJER diffusers . . . . . assuring

50% More CO_2
Clean, Tasteless Gas
100% Combustion
Unique Absorption Method
Economical Operation
Factory Tested Package System

Write for bulletins 7W83 - 7W85 and 7W88

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA, ILLINOIS

(Continued from page 68 P&R)

to material of pipes, authors point out that there may be, in water, bacteria capable of attacking synthetic materials, and emphasize necessity for control of production of pipes used for water supply.—*WPA*

EVAPORATION CONTROL

Water Reservoir Evaporation Control. R. DRESSLER & A. JOHANSON. *Chem. Eng. Progr.*, 54:1:66 ('58). Water demands in US are constantly increasing and it is therefore becoming increasingly necessary to prevent loss of water by evapn. from reservoirs and lakes, especially in hot, arid climates. Examples of magnitude of this loss are given for various states. Previous work on use of monomolecular films to retard evapn. and on theory of action and characteristics of these films is reviewed. Methods of application of films involve either use of floats containing fatty alcohol particles, or, particularly in large reservoirs, continuous application of a fluid containing fatty alcohol (suspension process). Tests to ensure complete coverage of water surface by film include observations of effect of dropping a pinch of camphor or of finely powdered fatty alcohol on to surface; pressure and effectiveness of film can be estd. by a technique involving addn. of various indicator agents with known surface tension effects. In a series of trials carried out on a 50-acre reservoir near Eagle Pass, Tex., evapn. was reduced by 30–40% when suspension process was used over 10–12 hr periods. More carefully controlled trials at a 2-acre reservoir gave a reduction of 60%. Examples are given of cost of treatment with fatty acids.—*WPA*

Use of Cetyl Alcohol in Solution to Reduce Evaporation From Reservoirs—Report on an Experiment on Malya Reservoir in Tanganyika Territory, in August 1957. F. GRUNDY. *Mem. E. Afr. Met. Dept.*, 11:11 ('58). A controlled expt. was commenced in Aug. '57 on a larger reservoir in order to det. whether it was possible to maintain a film on a water surface which

(Continued on page 72 P&R)

WATER STORAGE TANKS

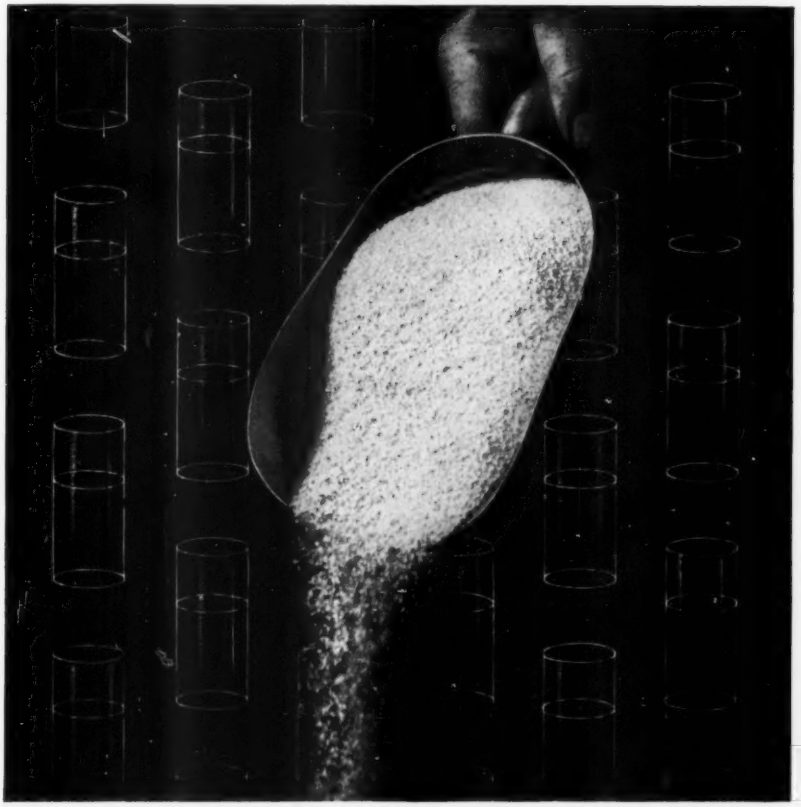
ELEVATED
GROUND RESERVOIRS
STANDPIPES

Complete Tank Service

Engineered and Erected According to
AWWA-AWS-FIA-FM and NBFU Specifications

TAYLOR IRON WORKS
MACON, GEORGIA
Serving The Southern States Since 1898

Please Address Inquiries To
Box 218 Macon, Ga. Box 6493 Jacksonville 5, Fla.



One pound of HTH chlorinates 3,200,000 glasses of water*

. . . but the economy and effectiveness of HTH are only part of the story! You should also consider the convenience of this easy-to-store, and easy-to-use *dry* chlorinating product.

Consider, too, HTH's wide range of applications. Wherever germs, fungi or bacteria threaten—in pipe lines, reservoirs, wells, filtration equipment, as well as during emergency flood conditions—you get fast, dependable chlorination with HTH.

HTH, containing 70% available chlorine, is made in granular and tablet form. Both products are proved by over 25 years of successful service in almost every phase of water treatment. Check your supply house or write us today.

*0.5 ppm available chlorine treatment

HTH

OLIN MATHIESON CHEMICAL CORPORATION
CHEMICALS DIVISION • BALTIMORE 3, MD.
HTH® is a trademark

4362

(*Continued from page 70 P&R*)

was subject to greater disturbance by waves, and also amt. of cetyl alcohol required under these conditions. In accordance with recommendations made in previous report, reservoir selected was Malya reservoir, in Tanganyika, 60 mi south of Mwanza; it has a surface area of about 130 acres, of which about 20 acres are covered with aquatic vegetation. Hydrology of reservoir is carefully considered. Exptl. procedure was similar to that used with smaller reservoirs, a further correction being applied to results to allow for surface of water covered by vegetation. Cetyl alcohol preparation used contained 45% cetyl alcohol, 4% stearyl alcohol, 10% myristyl alcohol, and 5% unsaturated alcohols; solvent used was paraffin; and a spreading agent was also added to soln. Details are given of calcn. of results from measurements of fall in water level and pan evaporation with and without cetyl alcohol treatment. Attempts are made to explain comparatively small reduction in evapn. (11%) which was achieved and large amt. of cetyl alcohol consumed (0.75 gal/acre/day). Expt. indicated, however, that a film of cetyl alcohol can be established on a water surface disturbed by wind of an avg. velocity of about 15 mph sustained for periods up to 4 hr, and having a fetch of about 1,000 yd.—*WPA*

Fatty Alcohols for Water Conservation. I. McARTHUR & K. DURHAM. *Proc. Intern. Congr. Surface Activity, 2nd* (London), 1: 262 ('57). Efficiency of com. fatty alcs. is compared with that of cetyl alc. (**I**) in retardation of H_2O evapn. Eight mixts. of alcs., consisting of varying amts. of **I**, myristyl (**II**), stearyl (**III**), satd. C_{20} and C_{22}, and unsatd. alcs., were used in study. Data given show that film spreads faster from small beads and from beads with a cryst. surface. Mixed **I** and **III** alcs. spread nearly as fast as 90% **I**. Spreading velocities were increased by the incorporation of 5–8% oleyl alc. (**IV**) in mixt. Most efficient spreading occurred when a soln. or a powder was used. Addn. of a surface-active agent offered no advantage in spreading; it decreased evapn. resistance. Most efficient mixt. of those studied in reducing evapn. from both quiet and wind-agitated (7.5 mph) surfaces was a mixt. contg. **II** 10, **I** 45, **III** 40, and unsatd. alc. 5%. The addn. of increasing amts. of **IV** was detrimental. This mixt. has a recovery power equiv. to that of 90% **I**. The effect of wind on generation and properties of monolayers of fatty alcs. is reported. —*CA*

Reduction of Evaporation From Reservoirs. F. GRUNDY. *Proc. Intern. Congr. Surface Activity, 2nd* (London), 1:270 ('57). A method is described in which hexadecyl alc. (**I**) is used to reduce evapn. from reservoirs by the addn. of a soln. of **I** in kerosine (paraffin oil, 30 g/l) with addn. of 0.9 g/l Pluronic F68, a spreading agent. Methods of applying soln. in various field expts. are described, as well as the computations to det. the reduction in evapn. from reservoirs. Reductions in evapn. were 25–30%. The **I** contg. largest proportion of stearyl alc. was most efficient.—*CA*

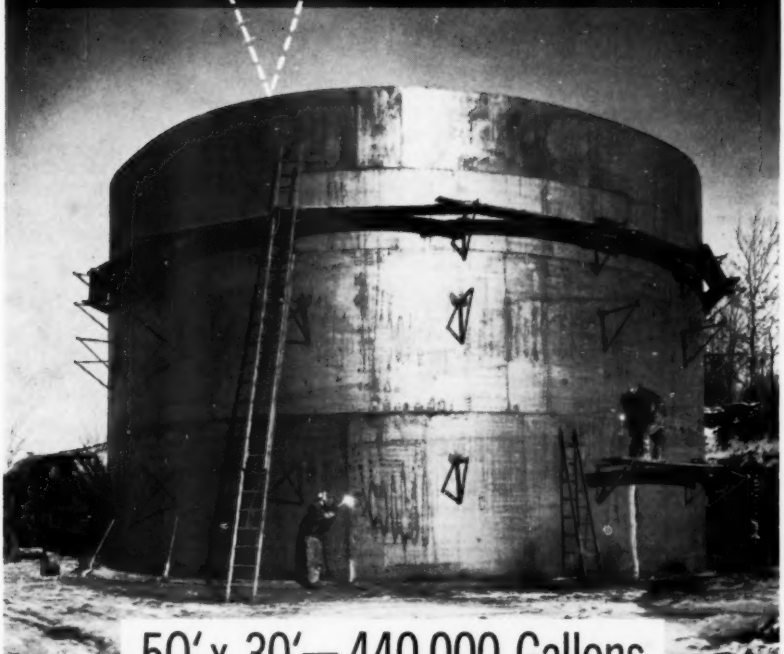
Influence of Monolayers on Evaporation From Water Storage. II. Evaporation and Seepage From Water Storage. W. W. MANSFIELD. *Australian J. Appl. Sci.*, 10:65 ('59). Influence of depth of water upon annual evaporative cycle of a storage and relations between storage evapn. and losses from an evaporimeter are discussed. Seepage losses can be detd. from variations in tot. chloride-ion content. **III. Action of Wind, Wave, and Dust Upon Monolayers.** *Ibid.*, 73–84. Rupture and reduction of monolayers on exposed water surfaces by wind, wave, and dust are discussed, and estimates made of resulting losses of material from a monolayer of cetyl alcohol.—*CA*

DISINFECTION

On the Use of Active Iodine as a Water Disinfectant. S. L. CHANG. *J. Am. Pharmaceutical Assn., Sci. Ed.*, 47:417 (Jun. '58). Chemistry of formation of various species of titrable iodine in aqueous solns. of elemental iodine and iodide is described in a quantitative manner. Relative cysticidal and viricidal efficiencies of various species of titrable iodine and effect of temp. on efficiencies of I_2, are described. Equations are given for computing cysticidal and viricidal titrable residual iodine in solns. of known amts. of iodide and pH. With I_2–I^- ratio and iodine demand, temp. and pH of water to be treated known, it is possible to compute dosage of titrable iodine for a fixed contact time in cyst or virus destruction. Author, however, feels that, as the virus (Coxsackie B1) is more resistant and as triiodide ion has

(*Continued on page 74 P&R*)

WATER TANK
MADE OF STEEL
to AWWA specifications



50' x 30'—440,000 Gallons

"Steel tanks store water best"

STEEL PLATE FABRICATORS ASSOCIATION
105 West Madison Street
Chicago 2, Illinois

(*Continued from page 72 P&R*)

a slight cysticidal, but no detectable viricidal, activity, computation should be based on virus rather than cyst destruction to give a wide margin of safety.—*PHEA*

Disinfection of Drinking Water by the Combined Action of Ultrasonic Waves and Small Doses of Disinfectants. L. I. ELIPINER. *Hyg. & Sanit.* (USSR), 23:7:26 ('58). Tests and equip. used in investigating effect of ultrasonic waves on coliform bacteria in water are described and results are tabulated and shown in a graph. It was found that, using ultrasonic waves alone, water can only be disinfected by exposure for 10–15 min., but in presence of small amts. of disinfectants, such as chlorine or hydrogen peroxide, disinfection is obtained with much shorter periods of exposure to ultrasonic waves. Running water was also treated by exposure to ultrasonic waves in presence of small doses of disinfectant and extent of disinfection depended on rate of flow of water, period of exposure to ultrasonic waves, and depth of water layer.—*PHEA*

The Effect of Chlorine in Water on Enteric Viruses. S. KELLY & W. SANDERSON. *Am. J. Public Health*, 48:1323 (Oct. '58). Complete inactivation of enteric viruses (beyond the limit of detection) was not achieved by usual conditions for bact. disinfection of water supplies—that is, free residual chlorine concns. of 0.2 ppm for 10-min contact at pH 7. Concns. of free residual chlorine of 0.2–0.3 ppm inactivated viruses after contact periods of 30 min. Contact periods of at least 4 hr were necessary for inactivation by combined residual chlorine concns. of 0.7 ppm. Factors which affected inactivation of viruses were strain, pH level, free residual chlorine concn., expesure time, and temp. Strains in decreasing order of their sensitivity to chlorine were as follows: Coxsackie B 5, poliovirus 1 (Mahoney), poliovirus 2, Coxsackie B 1, poliovirus 3 and poliovirus 1 (MK 500). Rises in pH value of 1 unit above pH 7 more than doubled contact period necessary for inactivation of several strains. Concns. of free residual chlorine of greater than 0.2 ppm for contact periods longer than 10 min were necessary for inactivation, depending on virus strain, temp., and pH level. A 20°C lowering of temp. slowed inactivation 2- to 15-fold. Results suggest that inactivation of enteric viruses in water at pH 7, 25°C, requires a min. free residual chlorine concn. of 0.3 ppm for contact periods of at least 30 min; at higher pH levels or lower temps., more intensive chlorination is necessary.—*PHEA*

New Procedures for Disinfection of Drinking Water. J. LEHMANN. *Z. Aerztl. Fortbild.*, 51:17:717 ('57); *Excerpta Medica, Public Health, Social Medicine & Hygiene*, 4:605 (Aug. '58). A critical discussion is given on pros and cons of nonautomatic chlorination as it is still practiced in many small water supplies. Replacement is recommended of chlorination with chloride of lime by treatment with a transportable apparatus for application of chlorine gas, which should be kept ready in every district in order to be put into action in a few hr, wherever condition of water supply may require such. Favorable results of this system are reported. In discussing automatic chlorination plants, various problems are referred to: dependence of their efficiency on quality of the water, their trustworthiness in regard to bactericidal effect on various pathogenic microorganisms, and, on other hand, influence of chlorination on palatability of water. As regards more modern procedures following are discussed: application of chlorine dioxide, ozone procedure, system based on oligodynamic effect of silver, photonic procedure, and, finally, disinfection by alteration of hydrogen-ion concn.—*PHEA*

BACTERIOLOGY

Nutrition and Metabolism of Marine Bacteria. VII. Growth Response of a Marine Flavobacterium to Surface-Active Agents and Nucleotides. R. MACLEOD; H. HOGENKAMP; & E. ONOFREY. *J. Bacteriol.*, 75:460 ('58). An organism designated B4, isolated from sea water and tentatively identified as a Flavobacterium, could not previously be grown in a medium supplemented with amino acids and vitamins unless yeast extract was also added. An account is now given of development of a chemically defined medium suitable for growth of this organism. In a medium containing 18 amino acids and 2 vitamins, growth-promoting effect of yeast extract for organism could be largely but not completely replaced by a mixt. of a surface-active agent and 3 nucleotides. Comp. of basal medium and results obtained in tests with various growth-promoting agents are

(*Continued on page 76 P&R*)

the bigger your pumping problems . . . the better your reasons for giving them to

WHEELER-ECONOMY

You know how big problems can be, in selecting pumps for water works reservoir service. The Pumps you see here are specially designed and built to solve such problems. They're 36″ Axial Flow Wheeler-Economy Pumps, each of which delivers 28,000 gpm. And they've been in continuous service for many years with only routine maintenance and modest operating costs.

If you're puzzled over which pumps to use for water works, municipal or industrial power plant service, drainage, irrigation or flood control, see C. H. Wheeler. Your representative can help you even if you need capacities exceeding 220,000 gpm and heads of 75 feet. He'll give you expert advice on pump design and construction, and station arrangement suggestions you'll find helpful.

Economy Pump Division

C. H. WHEELER MFG. CO.

19th and Lehigh Avenue • Philadelphia 32, Pa.

Whenever you see the name C. H. Wheeler on a product, you know it's a quality product

Centrifugal, Axial and Mixed Flow Pumps • Steam Condensers • Steam Jet Vacuum Equipment • Marine Auxiliary Machinery • Nuclear Products

(*Continued from page 74 P&R*)

tabulated. All surface-active agents tested promoted growth when present in medium in low concns. Individual nucleotides and combinations of 2 nucleotides reduced rate of growth of bacterium; only when 3 nucleotides were present in medium together was there an increase in rate of growth. Flavobacterium also required biotin, thiamine, a complex mixture of amino acids, and sodium, potassium, magnesium, and calcium ions for growth.—*WPA*

Studies on the Differentiation of Coliform Bacteria in Examination of Water. R. SCHUBERT. *Z. Hyg. Infektionskrankh.*, 144:495 ('58). Tests are described on differentiation of coliform bacteria using Mura medium, methyl red reaction in normal glucose medium and in a lactose medium, and EMB agar. From point of view of differentiation of coliform bacteria in examn. of water, none of these gave completely satisfactory results. Daranyi's thermal death-point test was not found suitable. Further tests are described using indole-mannitol medium which gave satisfactory results. Details of technique of test are given.—*WPA*

Effect of Sudden Chilling on *Escherichia coli*. G. G. MEYNELL. *J. Gen. Microbiol.*, 19:380 ('58). Expts. have shown that *Esch. coli*, growing in broth at 37°C, is rendered incapable of multiplication either on nutrient agar or in nutrient broth by sudden cooling in many diluents at 4°C. Killing appears to be due to joint action of a suitable diluent and of sudden chilling, as survival was complete after either sudden chilling in 0.3*M* sucrose or gradual cooling in a potentially lethal diluent such as Ringer's soln. Organisms in stationary phase of growth were completely resistant, and susceptibility of growing organisms to sudden chilling changed rapidly during exponential phase. Comparison with survival after exposure to streptomycin, another bactericidal agent which has no effect on stationary phase cultures, showed that survival after chilling was not due to a fraction of pop. being in stationary phase. Sudden cooling of *Esch. coli*, strain B, infected with phage T2, had same effect as ultrasonic disruption—destruction of infective centers in 1st half of latent period followed, in 2nd half, by release of intracellular mature phage.—*WPA*

Observations on the Isolation of *Salmonella typhi* From Water by the Precipitation Method. M. PANDELESCU & I. ROSU. *Igiena* (Budapest), 6:357 ('57). A study has been made of isolation of *Salmonella typhi* from water by pptn. with potassium aluminium sulfate. Best results were obtained with 5 cc of a 15% soln. of coagulant per liter of water; this gave a heavy precipitate which settled completely in 4 hr. pH value fell to 5.6, and was readjusted subsequently to 7.3 with sodium hydroxide. Ppt. of aluminium hydroxide with entrained organisms was redissolved in a small amt. of pH 7.4 phosphate buffer, and inoculated on to Wilson-Blair medium. Method gave satisfactory results with samples of water naturally infected with *Salm. typhi*.—*WPA*

Investigations on the Viability of Pathogenic Organisms in Water Supplies and Surface Water. P. KRAUS & G. WEBER. *Zbl. Bakt., I*, 171:509 ('58). Investigations are described on viability of *Salmonella typhi*, *S. paratyphi* **B**, and a virus in a well water suitable for supply, surface water from a dam, and a moorland water. Details are given of methods of expt. and of detection of organisms. In surface water *S. typhi* was detectable for up to 26 days and *S. paratyphi* **B** was still present when expt. ended after 70 days. Course of reduction of nos. of bacteria was not regular and was affected by comp. of water and temp. Temp. (between 4° and 22°C) did not affect viability of virus, in which reduction was steady and similar in all 3 types of water. Virus used, tested by subcutaneous injection into mice, was detectable up to 47 days after beginning of expt. Results show that infection of a water with virus or *Salmonella* remains a danger, regardless of season, for many weeks. —*WPA*

Counting of Sulfate-Reducing Bacteria in Mixed Bacterial Populations. Y. MALEK & S. RIZK. *Nature* (London), 182:538 ('58). A method is described for isolation and counting of sulfate-reducing bacteria in mixed bact. popns. In dilution method of counting *Desulphovibrio*, a selective medium containing lactate and inorganic salts is usually used, and growth of a sulfate reducer is recognized by appearance of black ferrous sulfide. As these organisms are anaerobes, a reducing agent must be added to medium.

(*Continued on page 78 P&R*)

PHOTOVOLT
pH Meter Mod. 115

A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

$175

- SIMPLE IN OPERATION AND MAINTENANCE
- FAST AND DEPENDABLE IN SERVICE

Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters

PHOTOVOLT CORPORATION

95 MADISON AVENUE NEW YORK 16, N. Y.

Also: Multiplier Photometers, Exposure Photometers for Photomicrography, Hemoglobinometers, Glasmeters, Polarimeters, Foot-Candle Meters, Interference Filters, Mirror Monochromators

(Continued from page 76 P&R)

Cysteine has been used, but culture has to be incubated anaerobically, and false positive results may be obtained as cysteine may be attacked by certain bacteria which produce sulfide, but do not reduce sulfate. A confirmatory test for *Desulphovibrio* was therefore necessary. Studies on action of *Desulphovibrio* on iron and effect of iron on growth of organism are outlined; detailed expts. on replacement of cysteine by iron are described, and a comparison of 2 reducing agents is given in a table. Iron was tested as a reducing agent in medium used by Starkey and it was found to be satisfactory. Culture did not have to be incubated anaerobically, and iron did not give false positive results.—*WPA*

Comparative Studies on the Presence of Bacteria of the *E. coli* Group and Bacteriophages of Some Pathogenic Intestinal Bacteria in River Water. S. ZIEMINSKA. *Roczniki Panstwowego Zakladu Hig.* (Warsaw), 9:3:225 ('58). Detns. have been made of *Esch. coli* titer and titer of *S. typhi* Vi, *Shigella flexneri* and *S. paratyphi B* phages in 95 samples of water taken over course of 1 yr from River Vistula between Warsaw and Plock. Phage titrations were carried out on samples treated with thymol for 48 hr at 4°C in order to kill bacteria, and subsequently enriched by incubation for 24 hr in the presence of appropriate host bacteria. 273 cultures of phage were thus obtained, but were found to be mixtures of strains requiring further passages for their sepn. A striking feature of the results was frequency with which phage was detected in smallest volume of water (0.001 cc) among range examined. No correlation could be observed between *E. coli* titer and titer of any of phages isolated, and it is concluded that detn. of phage titer is not suitable for routine examn. of water.—*BH*

Concerning the Causes of Failure of TTC-Medium in the Bacteriologic Examination of Water Together With Proposals for Their Elimination. F. SELENKA. *Arch. Hyg. u. Bakteriol.*, 142:4:241 (Jun. '58). Bact. counts on water samples obtained with various nutrient agar media containing TTC differed from those obtained on Endo agar used as reference by 0–100%. It was found that counts on TTC agar were dependent upon composition and preparation of agar medium, and it was concluded that ordinary nutrient agar is therefore not applicable as a basis for TTC agar in the bacteriologic analysis of water. Trouble is due to absence of ions which activate dehydrogenase which is precipitated in increased quantities as sparingly soluble phosphate compounds by addn. of phosphate or by making medium strongly alkaline before sterilizing it. Acidification or addn. of calcium ions in form of calcium chloride ($CaCl_2$) avoids this trouble. A satisfactory medium can be produced if following precautions are taken: omission of phosphate, slight acidification before sterilization, standardization of pH to 0.1 shortly before pouring plates, and addn. of 0.2% of a sterile soln. of calcium chloride added simultaneously with tetrazolium salt. Preparation of a solid nutrient medium containing TTC for differentiation between old and recent fecal contamination is possible.—*BH*

Removal of Coxsackie and Bacterial Viruses in Water by Flocculation. I. Removal of Coxsackie and Bacterial Viruses in Water of Known Chemical Content by Flocculation With Aluminium Sulfate or Ferric Chloride Under Various Testing Conditions. S. L. CHANG ET AL. *Am. J. Public Health*, 48:51 ('58). In an investigation to determine how certain pathogenic viruses differ from bacterial viruses in their behavior during coagulation, it was found that during coagulation with alum amt. of both Coxsackie and bacterial viruses removed increased with increasing doses of alum, but that bacterial virus was more readily removed than Coxsackie virus. Log-log relation between ratio of percentage removal of viruses to dose of alum and percentage of virus remaining in water was linear; an increase of 2- to 2½-fold in dose of alum caused a 10-fold decrease in concn. of virus. Optimal pH value for removal of both viruses was in range 6.2 to 7.2 with bicarbonate buffer, but with phosphate buffer, effect of pH value was less critical. Reducing rate of stirring from 81 to 36 rpm caused a reduction in percentage of Coxsackie and bacterial viruses removed from 97.1 to 93.6 and 99.1 to 93.8%, respectively. Ferric chloride was more effective than alum in removing these viruses under conditions of expts.; removal of bacterial virus was consistently greater than that of Coxsackie virus; and floc formed was more

(Continued on page 80 P&R)

WATER PRESSURE CONTROLLED

G-A *Cushioned* Water Pressure Reducing Valve

Like the elephant, water pressure can be big trouble if not controlled. That's what the Golden-Anderson Pressure Reducing Valve does. This sensitive valve always delivers water at the same predetermined pressure . . . regardless of upstream variance. No need to fear water line damage from high initial pressures with this Golden-Anderson Valve on the job.

Write for Bulletin W-3A

GOLDEN ANDERSON *Valve Specialty Company*

1221 RIDGE AVENUE, PITTSBURGH 33, PA.

Designers and Manufacturers of VALVES FOR AUTOMATION

(Continued from page 78 P&R)

compact, settled more rapidly, and showed less tendency to virus-floc dissociation than that formed with alum. Ferric chloride in doses of 20 and 40 ppm removed 96.6 and 98.1% of Coxsackie virus and 99.3 and 99.9% of bacterial virus respectively, compared with 86.3% removal of Coxsackie virus and 93.5% removal of bacterial virus when 40 ppm aluminum sulfate was used. **II. Removal of Coxsackie and Bacterial Viruses and the Native Bacteria in Raw Ohio River Water by Flocculation With Aluminium Sulfate and Ferric Chloride.** *Ibid.*, 48:159 ('58). Expts. were carried out on efficiency of a 2-stage coagulation process for removing Coxsackie and bacterial viruses and native coliform and total bacteria from raw Ohio R. water at 5°, 15°, and 25°C; on critical time in relation to floc formation for removal of these viruses and *Esch. coli* during coagulation process; and on interfering effect of gum arabic on the removal of viruses and bacteria by coagulation with alum. In first stage of coagulation in river water with a turbidity of less than 260 ppm, reductions in Coxsackie virus of 95 and 99% were achieved at 5°–15°C and 25°C respectively, using 25 ppm alum (44 ppm filter alum). With 15 ppm alum, reduction at 25°C was 95.7%. There was no significant difference between removal of *Esch. coli* and of tot. bacteria in same sample. Removal of bacteria was slightly higher than removal of Coxsackie virus with 25 ppm alum, and significantly lower with 15 ppm alum. Removal of bacterial virus was slightly, but consistently, lower than that of Coxsackie virus. Efficiency of ferric chloride, used in second stage of coagulation, for removal of virus was comparable to that of alum, but its efficiency for removal of bacteria was lower. These relatively poor results were attributed to poor floc formation as a result of inadequate turbidity. Lower bacterial removal was enhanced by interfering effect of about 100 ppm calcium and over 10 ppm magnesium, an effect which was exaggerated at lower temps. Overall removal of Coxsackie virus, using 25 ppm coagulant in each stage, was 99.6% at 5° and 15°C, and 99.9% at 25°C; with 15 ppm coagulant, overall removal was 99.8% at 25°C. Corresponding reductions in bacterial numbers at 25°C were 98.99 and 99.99% with 15 ppm and 25 ppm coagulant respectively, and about 99.99% with 25 ppm coagulant at 5°C and 15°C. In general, greater removal of Coxsackie virus than of bacterial virus occurred. Presence of calcium and magnesium ions in raw water and addn. of calcium oxide in 2nd stage were believed to have interfered with formation of coagulant-cation bacterial-virus complex. Critical time for the formation of coagulant-microorganism complex in relation to removal of viruses and *Esch. coli* by practical doses of alum at 25°C was confined to 1st few minutes after addn. of coagulant. Removal of about 60% of Coxsackie and bacterial viruses by 360 ppm alum when viruses were introduced 30 min after addn. of alum was attributed to presence of a small amt. of aluminium ion in combination with this large coagulant dose. Gum arabic in a concn. of 20 ppm was found to prevent completely formation of floc and removal of Coxsackie and bacterial viruses and native bacteria by 15 ppm alum in raw Ohio R. water. Based on results of these expts., some suggestions are made for obtaining max. removal of viruses, as well as bacteria and other particulate matter, from water by coagulation.—*WPA*

SELF-EXPANDING CORK

THE JOINT MATERIAL THAT "GROWS" AFTER COMPRESSION
SELF-EXPANDING CORK IN JOINT
Normal Opening
JOINT COMPRESSED
CONTRACTED JOINT
Self-Expanding Cork Filler Expands Up To 50% Beyond Original Thickness

...keeps joints filled under maximum contraction

Specify and use Servicised SELF-EXPANDING CORK premolded joint filler in water and sewage treatment plants, canal linings and structures, outlet works, spillways and stilling basins in dams—and any other project where it is essential to keep the joints filled when contraction may open them up to more than original size.

Self-Expanding Cork Joint is formed from clean, granulated cork particles securely bonded together by an insoluble synthetic resin binder. It is specially treated to expand as much as 50% beyond original thickness. Fully compressible, non-extruding and resilient, Servicised Self-Expanding Cork is available in ½", ¾" and 1" thicknesses and lengths up to 10 ft.

Write for your copy of the new Servicised Catalog. It contains complete information on Self-Expanding Cork, as well as many other types of premolded joint fillers, and the Servicised line of hot and cold applied joint sealers we manufacture.

See our Catalog in Sweets.

SERVICISED PRODUCTS CORP.

6051 West 65th Street **Chicago 38, Illinois**

The Reading Meter

Ward & Whipple's Fresh-Water Biology. *W. T. Edmondson, ed. John Wiley & Sons, Inc., 440—4th Ave., New York 16, N.Y. (2nd ed., 1959) 1248 pp.; $34.50*

Since its publication in 1918, Ward and Whipple's *Fresh-Water Biology* has been the most frequently used single source of information about North American freshwater fauna and flora, but for many years it has been very much out of date. The new edition meets the long felt need for a concise guide to North American freshwater biota. The book consists essentially of a series of illustrated (black and white) keys, each preceded by expository material. Although the user is expected to have a general knowledge of the morphology and life history of the groups he intends to study, the book is intended for a wide audience. Sanitary engineers will find it of aid in many investigations where identity of organisms is of central importance. And as a general reference work in the field, the new volume should prove invaluable.

Algae in Water Supplies. *C. Merwin Palmer. Public Health Service Publication No. 657, Government Printing Office, Washington 25, D.C. (1959) 88 pp.; $1*

Prepared at the Taft Sanitary Engineering Center, Cincinnati, this manual on algae identification, significance, and control is designed primarily for water plant operators. It includes many black-and-white illustrations as well as six pages of excellent color plates by Harold J. Walter. There are chapters on taste and odor algae, filter-clogging algae, polluted-water algae, clean-water algae, and others. Tabular material on nomenclature, a list of keys to identification, a glossary of relevant technical terms, a bibliography, and an index of species are other useful features. Every plant faced with algae problems should have a well-thumbed copy on the shelf.

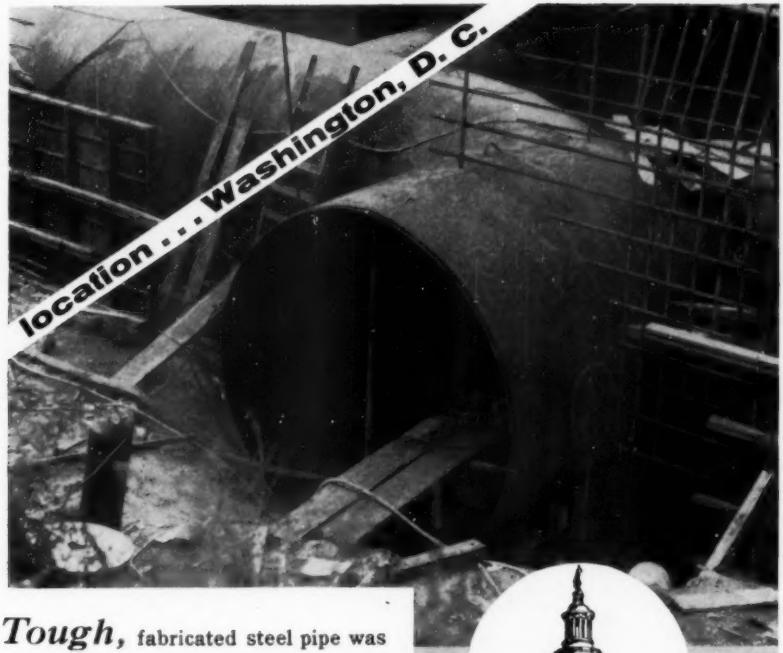
The World Beneath the City. *Robert Daley. J. B. Lippincott Co., E. Washington Sq., Philadelphia, Pa. (1960) 223 pp.; $3.95*

This is a story, first, of water supply, not only because water mains—the wooden water mains of Aaron Burr's Manhattan Company—were the first invaders of the world beneath New York City, but because water supply, more than anything else in the underground world, has permitted New York City to grow and prosper. This fact Robert Daley makes dramatically clear in his exposition of the early history of the city's water supply, just as he makes clear that the growth and prosperity were unconscionably delayed by Burr's political machinations. Burr, he says,

> had hoped to parlay "pure and wholesome" water into making himself president, then emperor. No demagogue had ever used water as a weapon of conquest before, and Burr might have succeeded if his water had been of better quality. But the water which coursed through the wooden pipes was foul, and quenched the thirst of no man, least of all Aaron Burr.

But the story of how despite politics and despite tremendous engineering prob-

(*Continued on page 84 P&R*)



Tough, fabricated steel pipe was the logical choice for the new water pumping station completed in Washington, D. C. by Morgan Steel Products.

Buried in the bed of the Potomac River, steel pipe ranging in diameter from 24″ to 10 feet with coal tar enamel lining was used in conjunction with a complicated system of fittings, settling basins and filters. Steel pipe made the installation job easy and most economical . . . with assured long life.

Steel pipe is *universally* specified for the toughest assignments because of its Superior Strength, Bottle-Tight Joints, Ductility and Durability. Morgan is the logical choice for accomplishing this work.

"Wherever Water Flows—STEEL PIPES IT BEST"

Morgan Steel Products, Inc.
CUSTOM STEEL FABRICATORS
Working ... Tanks ... Chutes ... SMOKESTACKS ... HOPPERS ... BATCHINGS ...
3700 MORGAN AVENUE • CLEVELAND 27, OHIO • Michigan 1-3200

The Reading Meter

(Continued from page 82 P&R)

lems, the city finally did bring in a good water supply, and the description of how that water supply was greeted by the public, makes exciting reading for anyone interested in water supply and concerned with its present problems.

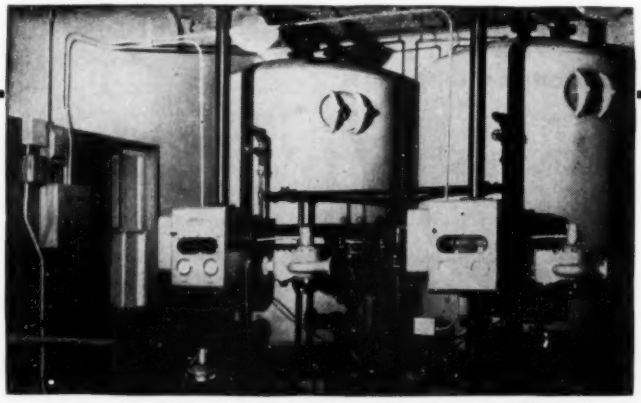
And the rest of the book, which threads the "spaghetti" around New York's water mains and introduces the personalities in the city's underground history is interesting, too, for there is only one of New York City—only one metropolis whose basement is packed with 5,500 mi of water mains, 5,000 mi of sewers, 7,000 mi of gas mains, 2,200 mi of TV cables, 15,000,000 mi of telephone wires, 19,000 mi of electric cable, 87 mi of high-pressure steam lines, and 726 mi of subway tracks, carrying no less than 8,700 trains per day.

This is a book that will inform, if not instruct, you—a book that is certain to entertain you. And it does tell you all about the alligators in New York City's sewers!

The Structures of Eduardo Torroja. *Eduardo Torroja. F. W. Dodge Corp., 119 W. 40th St., New York, N.Y. (1958) 198 pp.; $8.50*

Only very occasionally does one find a book of such compelling interest as this. Dr. Torroja is a most perceptive and accomplished engineer, architect, and artist, and which of these categories should be listed first is problematic. His work, in reality, is a full and harmonious fusion of these three facets. In addition to his practice as a consulting engineer he also founded and now directs the Technical

(Continued on page 86 P&R)



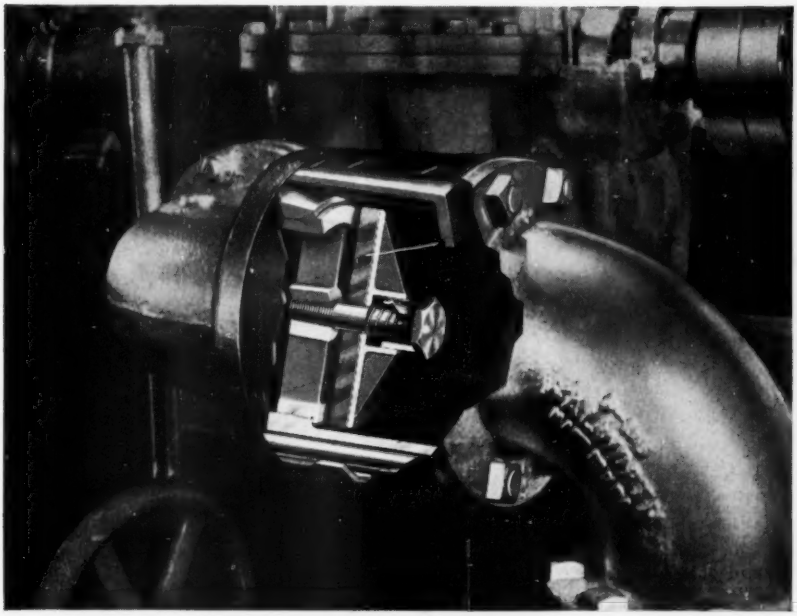
Iron and Manganese Removal Plus Water Softening . . .
Automatically by Ion-Exchange using Invercarb C-110

Low in cost—efficient in operation. Send for Particulars.

H&T SERVICE

HUNGERFORD & TERRY, INC.

CLAYTON 5, NEW JERSEY



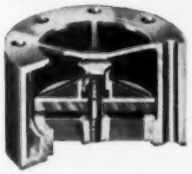
ELIMINATE BACK-DROP, SURGE AND HAMMER

When CPV silent, non-slam check valves are installed on the discharge of centrifugal pumps, the whole system is protected against waste and harmful surges. The need for expensive air cushions and other anti-hammer devices is eliminated.

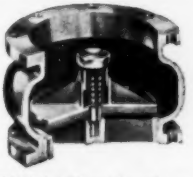
Spring-actuated, CPV check valves close automatically as soon as flow ceases. Back travel, which can be so damaging, is not required for closing.

Users report CPV valves easy to install and require no maintenance. Unique design includes bearing guides on both sides of disc and a full flow area in excess of pipe area. The valve operates in any position.

For complete specifications and prices write Combination Pump Valve Company, 853 Preston Street, Philadelphia 4, Pa.



STYLE "G"—2 to 10"



STYLE "GB"—6" and up

CPV SILENT NON-SLAM CHECK VALVES

Faster LOCATING!

LOWER SERVICE COSTS

with the improved AQUA VALVE BOX LOCATOR!

Your Name In Gold FREE!

$32.50 F.O.B. Cin., Ohio

STOCK this useful tool for every service CAR and CALL • Speed Locating • Keep Customers Happy

- NO WIRES, BATTERIES or SWITCHES—simple, powerful magnetic action, factory adjusted to YOUR geographical location assures unfailing results!
- NO NEEDLE SPINNING—exclusive electric braking action saves you time!
- NO STOOPING—easy top-view reading!
- RUGGED—compact, accurate, convenient!
- GUARANTEED—to function regardless of weather, surface or ground cover!
- NATION'S MOST WIDELY USED LOCATOR!
- 15-DAY FREE TRIAL—No money! No obligation! You be the judge!

ORDER NOW - Wire or Call Kirby 1-4200 collect

AQUA SURVEY & INSTRUMENT CO.

2028 Leslie Ave., Cincinnati 12, Ohio

FIND LEAKS FASTER

WITH THE AQUA SURVEY AQUAPHONE

Only $4.50 EACH 6 for $25.00 ORDER NOW

RUGGED! SENSITIVE!

Super-sensitive scientific pre-tuned diaphragm without mechanical connection between diaphragm and probe, makes this the industry's most durable instrument. Genuine molded Bakelite case. Unconditionally guaranteed against mechanical failure for life of instrument! Order one for every service man. 2 Ft. probe Extension $2.25.

AQUA SURVEY & INSTRUMENT CO.

2028 Leslie Ave., Cincinnati 12, Ohio

The Reading Meter

(Continued from page 84 P&R)

Institute of Construction & Cement at Costillares, Spain, one of the world's outstanding model testing laboratories. His work often reflects this background, and his approach to design is fresh, functional, and uninhibited by precedent. From an architectural and esthetic viewpoint, his structures are completely beautiful and blend with their natural surroundings in a manner seldom achieved. The late Frank Lloyd Wright, noted more for his acrid comment on contemporary design than for praise, said of Torroja: "He has expressed the principles of organic construction better than any engineer I know."

The engineering, architectural, and artistic scope of Torroja is phenomenal, and is comparable to that of Leonardo da Vinci. The 30 structures described in photographs, line drawings, and text vary from racecourse grandstands and clubhouses to factories, hangars, bridges, and churches. Of particular interest to the water supply profession are his storage tanks, aqueducts, and dams. It cannot be said that Torroja's tanks hold more water than those in the United States, but it is factual that his concrete design reflects greater scientific appraisal of functional requirements, and his finished structures add considerably to the beauty of the terrain. North American engineers, in appraising his water tanks, may take small consolation that the formwork and bracing required for these configurations in concrete could be rather prohibitive, with the high costs of American labor today, and also that it might be difficult to find a community in America whose esthetic appreciation would lend the necessary moral and financial backing to the engineer for such a design.

This book is heartily recommended not only to engineers and architects, but to everyone with an appreciative sense of beauty of structure.—T. M. RIDDICK. *Cons. Engr., New York.*

(Continued on page 88 P&R)

Always fair weather

. . . the Dresser way

Lenoir, North Carolina engineered this 10-mile, 20-inch water supply line to supply an additional 3 mgd. Gilbert Engineering and Pat O. Chester Construction Co. laid the 100 per cent Dresser-Coupled steel piping in 40 and 50 foot lengths.

When you specify Dresser® Couplings, you are much less vulnerable to delays caused by bad weather. If your crew can get in the trench, they can make the connections. All you need is a simple hand wrench to make permanently tight joints . . . no need for expensive welding equipment, no costly weather delays! And unlike rigid joints, the non-rigid Dresser Coupling protects the pipe from ground movement and stresses, remains bottle-tight even when absorbing shocks which can create costly maintenance problems in other piping.

GET THE MOST FOR YOUR TAX-PAYER'S DOLLAR: Be sure to specify Dresser-Coupled steel pipe on your next water line for the *least initial cost, lowest maintenance!*

Two man-minutes per bolt make bottle-tight joints for life!

Bradford, Pennsylvania
Chicago
Houston
New York
S. San Francisco
Toronto & Calgary

DRESSER MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES

The Reading Meter

(Continued from page 86 P&R)

Technology in American Water Development. *Edward A. Ackerman & George O. G. Lof. Published for Resources for the Future, Inc., by Johns Hopkins Press, Baltimore 18, Md. (1959) 710 pp.; $10*

The book is divided into four general sections: (1) the physical and economic and environment of water development; (2) techniques and technical events significant in the progress of water development; (3) emerging technology of potential impact on water use; and (4) organizational responses to problems and opportunities for water development introduced by technologic change.

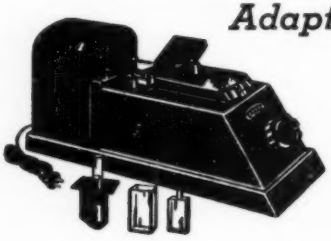
After a broad discussion of the location of water supplies over the United States, the seasonal uses, seasonal aspects of water demand, and the problems of matching the available supply with the demand, the volume goes into the technical events which have increased the demands for water, events which contribute to a decrease in demand, and methods of increasing the usefulness of a supply of water.

The next part discusses the development of techniques likely to influence the rate of water exploitation and the nature of the demand. For example, it is indicated that improvements in electric power generation practices require the use of less water for condenser purposes than was previously the case.

The volume is superior to many others which have been published in recent years in that it affords a very clear disclosure of the relationship between water resources as they are made available by nature and the uses to which men are putting them.—H. E. JORDAN.

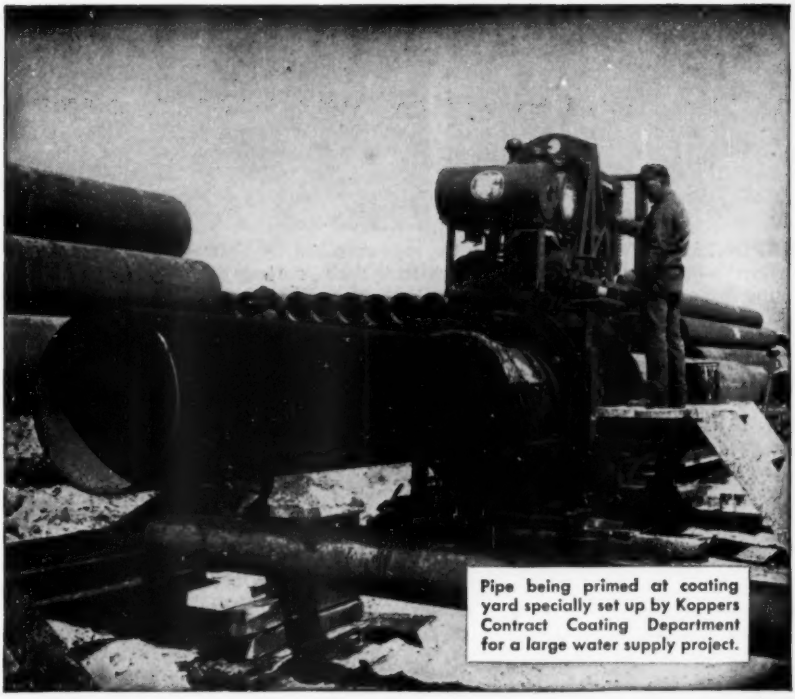
KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.



Pipe being primed at coating yard specially set up by Koppers Contract Coating Department for a large water supply project.

3/32" MAKES ALL THE DIFFERENCE

Steel water pipe will last much longer underground with the armor-like protection which a 3/32" coating of Bitumastic 70-B AWWA Enamel gives it. This corrosion-preventive coating is vital to the long-life of water lines.

Bitumastic Enamel has helped steel water lines set high flow capacity records of 40 years and more. Proven performance is one reason why so many water supply engineers are specifying steel pipe, lined and coated with Bitumastic 70-B AWWA Enamel, for their projects today. A lining of this enamel gives a uniformly smooth inside surface that has proved to have the highest flow coefficient available.

You can obtain more information about the economies of Bitumastic 70-B enameled steel pipe from Koppers Company, Inc., Tar Products Division, Dept. 110H, Pittsburgh 19, Pennsylvania.

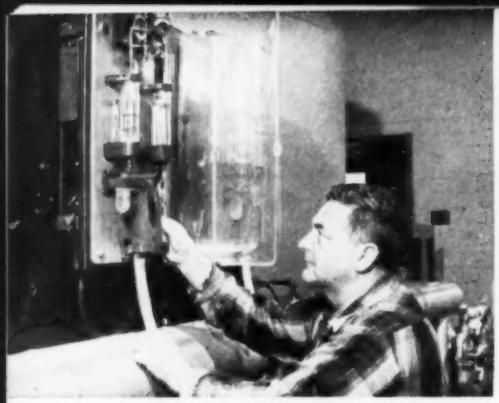
KOPPERS

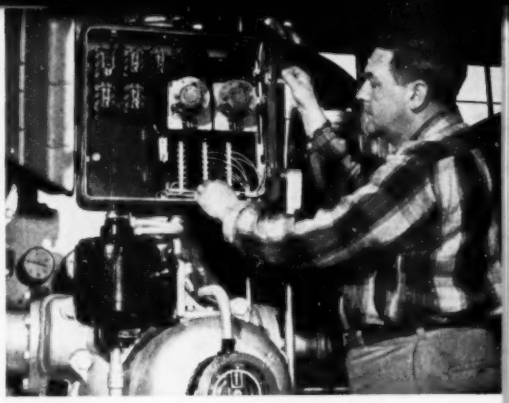
ONLY KOPPERS MAKES

BITUMASTIC

REG. U. S. PAT. OFF.

ENAMELS





HARDNESS TESTER (left) initiates regeneration by Automatic Controls (right). This new Permutit plant, with Q resin, softens 72% more water—using same manpower, less salt! E. Aurora, N. Y. Village Eng.: *E. J. Maurer.*

Why these cities chose PERMUTIT® *water conditioning*

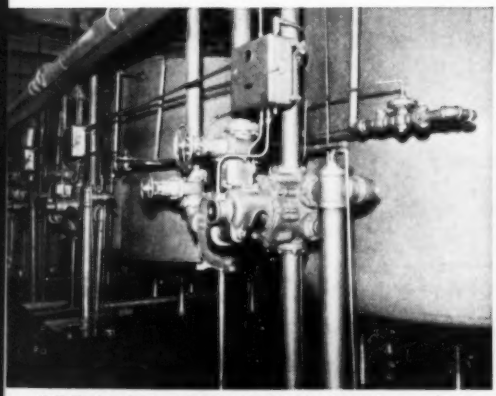
Some chose Permutit for its world-known engineering experience gained through thousands of installations covering every major development in clarification, filtration and softening equipment.

Others chose Permutit to get complete, integrated service: the water-analysis labs, engineering, equipment, controls, ion exchange resins—all from one source, under one responsibility.

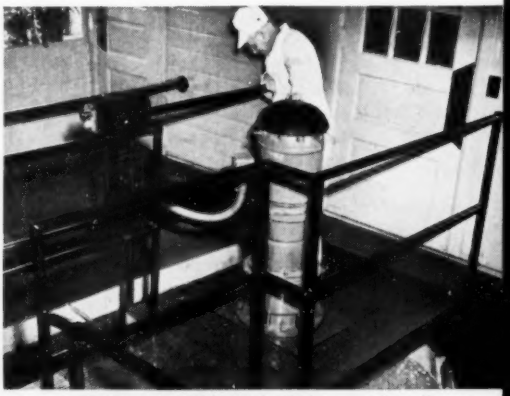
But most of the designers of these plants chose Permutit because they have personal knowledge of many installations where Permutit equipment has given long years of efficient, trouble-free performance. They know that's what pays off in the long run.

The Permutit Company, Dept. JA-10, 50 West 44th St., New York 36, N. Y. (a division of Pfaudler Permutit Inc.)

SOFTENERS • ZEOLITES and RESINS • AUTOMATIC CONTROLS • GRAVITY FILTERS • PRESSURE FILTERS
PRECIPITATORS • CHEMICAL FEEDERS • AERATORS • SWIMMING POOL SYSTEMS • IRON REMOVAL EQUIPMENT



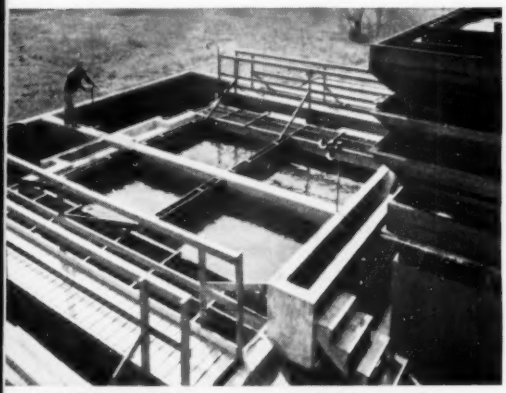
SOFTENER CAPACITY TRIPLED and $7,000 yearly saved on salt by change from zeolite to Permutit Q. Normal, Ill. Cons. Eng.: *Farnsworth & Conley.*



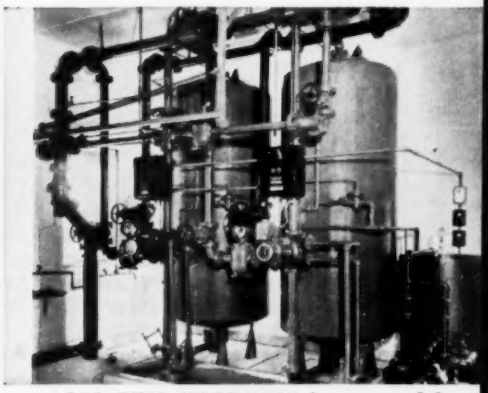
TRIPLE TROUBLE! 275 ppm hardness, 200 ppm alkalinity, 3 ppm iron are reduced by this Precipitator. Staples, Minnesota. Supt.: *E. H. Klang.*

TURBIDITY gets cut from 1500 to less than 5 ppm in this Precipitator. Mt. Carmel, Ill. Cons. Eng.: *Warren & Van Praag, Inc.*

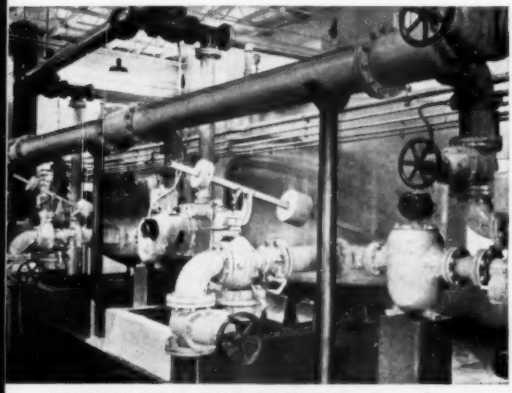
SEA WATER saves $32,980 per year over salt for regenerating Softeners. Hollywood, Fla. Cons. Eng.: *Reynolds, Smith & Hills.*



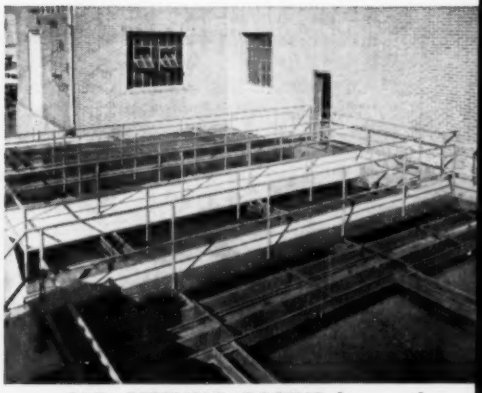
30 PPM IRON gets cut to 0.14 ppm in Aerator and Precipitator . . . even before filtration! Fairless Hills, Pa. Cons. Eng.: *H. H. Le Van, Jr.*



269 PPM HARDNESS is removed by these automatic Softeners. Aerator and Filters cut iron. Martinsville, Ill. Supt.: *O. Wiser.*



AUTOMATIC CONTROLS backwash, regenerate, rinse and return Softeners to service. New Smyrna Beach, Fla. Cons. Eng.: *Russell & Axon.*



OLD SETTLING BASINS house these modern Precipitators that boost capacity. North Kansas City, Mo. Cons. Eng.: *C. A. Haskins.*

Correspondence

Speedreading

To the Editor:

The photo at right shows one way our utility is combating the high cost of labor and speeding up the reading of water meters. In this example, we have installed five remote-reading dials arranged in such a way that the meter reader can read them all at once. All meters in this block have these dials, which are installed on the back of the buildings so the meter men can swing up the alley after reading one side street, read the dials in the alley, and then go down the next street. This saves a lot of time and walking for our meter readers and also proves no inconvenience to business places. At the present time we have installed 30 of these dials and are quite pleased with the results.

Installation is at city expense, which we feel is offset by eliminating bill estimation and the fact that only two men are needed for reading 14,500 meters

quarterly, plus the monthly commercials. We believe that it would have been necessary for use to hire another reader in the near future, because of the building of approximately 600 or 700 more new houses within the next year.

JOHN L. POWELL

Supervisor, Water Dept.
Lincoln Park, Mich.; Oct. 26, 1959

For further word on meter readers, see p. 36 P&R.—ED.

Too Deep Are the Roots

To the Editor:

In "Turbine Pumps for Booster Service," by Clinton C. Warren (October 1959 issue), the expression for specific speed is given as:

$$N\sqrt{\frac{Q}{H^{\frac{3}{4}}}}$$

(Continued on page 94 P&R)

Filter Sand and Gravel

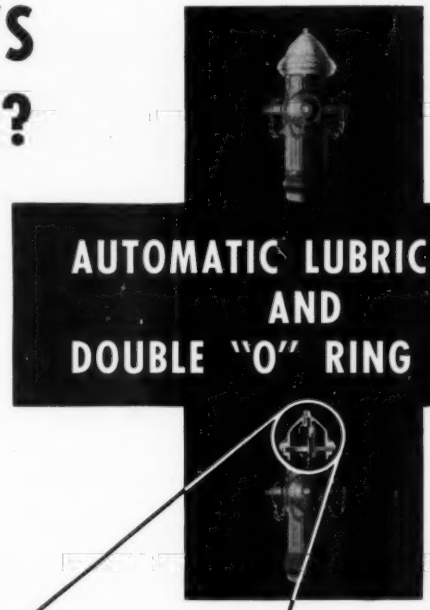
Well Washed and Carefully Graded to Any Specification.
Prompt Shipment in Bulk or in Bags of 100 lb. Each

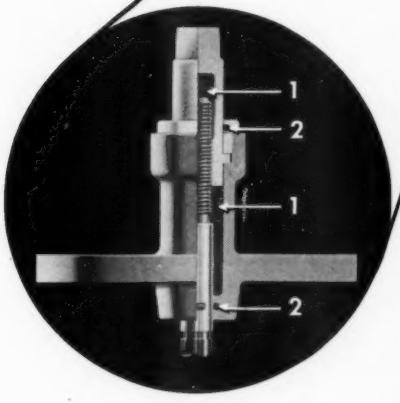
Inquiries Solicited

NORTHERN GRAVEL COMPANY

P. O. Box 307 **Muscatine, Iowa**

WHAT'S INSIDE? A BIG PLUS





Smith Fire Hydrants are easy to operate, inexpensive to maintain and most dependable in meeting severe climate and operating conditions. In addition to maximum flow and simplicity of design, Smith Hydrants now have two additional features of major importance: (1) Automatic lubrication — chamber sealed with "O" Rings contains a permanent type lubricant — temperature range–30° to 200°F. Each time the hydrant is operated, the threads and bearing surfaces are automatically lubricated. (2) "O" Ring Seals — the lower "O" Ring seals the internal pressure, the upper "O" Ring is a combined external dirt and moisture seal. This construction eliminates the conventional stuffing box and packing gland adjustments.

65

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY

Correspondence

(Continued from page 92 P&R)

It should be:

$$N\frac{\sqrt{Q}}{H^{\frac{1}{2}}}$$

since it derives from:

$$\frac{N}{\sqrt{H}}\sqrt{\frac{Q}{\sqrt{H}}} = \frac{N}{H^{\frac{1}{4}}}\frac{\sqrt{Q}}{H^{\frac{1}{2}}}$$

W. S. PARDOE

Merion Station, Pa.; Oct. 30, 1959

Reader Pardoe is right; the error resulted from the typesetter's misinterpretation of the marking in the manuscript. But why:

$$N\frac{\sqrt{Q}}{H^{\frac{1}{2}}}$$

rather than:

$$N\frac{Q^{\frac{1}{2}}}{H^{\frac{1}{2}}}$$

or, even better (and easier to set in type): $NQ^{\frac{1}{2}}H^{-\frac{1}{2}}$. *Or is the prejudice against negative exponents too strong?*—ED.

Pro AWUA

To the Editor:

Re: AWWA to AWUA? Tradition be damned, do it!

H. A. JANZEN

Kansas City, Kan.
Oct. 29, 1959

Shouldn't it be dammed rather than damned? Would other readers agree with H. A. Janzen's seconding of Arthur Rynders' motion (Correspondence, October 1959 issue, p. 104 P&R) to rename the Association "American Water Utilities Association"?—ED.

feco
LIGHTNING
SURFACE WASH BAFFLES
for RAPID SAND FILTERS
Increased velocity of backwash water in cleaning area above expanded sand doubles dirt carrying ability. Directs flow of water to wash troughs and puts all foreign matter in sewer. If filter develops uneven flow or "sand-boils," baffles deflect flow horizontally toward surface of sand in areas where vertical flow is restricted. Creates slight back pressure on filter above sand level, helping to equalize flow. Covers provide surface for precipitation of solids, reducing load on filter. Dirt can be washed off these surfaces into wash troughs.
WRITE FOR CATALOG NO. 5-2
FILTRATION EQUIPMENT CORPORATION
271 HOLLENBECK ST. · ROCHESTER 21, N.Y.

Drop your pipe problem

OVERBOARD

...with AMERICAN Molox Ball Joint Pipe!

Specify AMERICAN Molox Ball Joint Pipe for river crossings and other difficult installations. Molox pipe affords maximum installation economies because it is easily adapted to several installation methods: It can be floated or pulled across streams, or can be installed directly on the bottom from a barge. Once laid, it remains bottle-tight under pressures up to several hundred psi at any angle within the 15° range of deflection for which it is designed.

AMERICAN Molox Ball Joint pipe offers all the advantages of high strength Mono-Cast pipe with the socket cast *integrally* with the pipe; a heavy section alloy steel follower gland for added strength; plus the finest bolting of any flexible joint pipe available today . . . high strength, corrosion-resistant AMERICAN STAINLESS STEEL bolts.

Before "plunging" into underwater pipe installations consider the advantages of AMERICAN Molox Ball Joint Pipe. Write for free illustrated brochure or contact your nearest American Cast Iron Pipe Company representative.

AMERICAN CAST IRON PIPE CO.
BIRMINGHAM, ALABAMA

SALES OFFICES: Chicago
New York City — Kansas City
Dallas — Minneapolis — Denver
Pittsburgh-Orlando-Cleveland
Birmingham

Index of Advertisers' Products

Activated Carbon:
Industrial Chemical Sales Div.
Permutit Co.

Activated Silica Generators:
B-I-F Industries, Inc.—Omega
Wallace & Tiernan Inc.

Aerators (Air Diffusers):
American Well Works
Carborundum Co.
General Filter Co.
Permutit Co.
Walker Process Equipment, Inc.

Air Compressors:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Worthington Corp.

Alum (Sulfate of Alumina):
American Cyanamid Co., Process Chemicals Dept.
General Chemical Div., Allied Chemical Corp.

Ammonia, Anhydrous:
General Chemical Div., Allied Chemical Corp.
Jones Chemicals, Inc.

Ammoniators:
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Co., Inc.

Ammonium Silicofluoride:
American Agricultural Chemical Co.

Associations, Trade:
American Concrete Pressure Pipe Assn.
Cast Iron Pipe Research Assn.
Steel Plate Fabricators Assn.

Brass Goods:
American Brass Co.
Hays Mfg. Co.
Mueller Co.

Brine-Making Equipment:
International Salt Co., Inc.

Calcium Hypochlorite:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.

Carbon Dioxide Generators:
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.

Cement Mortar Lining:
Centriline Corp.
Halliburton Oil Well Cementing Co.
Southern Pipe Div. of U.S. Industries

Chemical Feed Apparatus:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Graver Water Conditioning Co.
F. B. Leopold Co.
Permutit Co.
Precision Chemical Pump Corp.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Chlorine Comparators:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Chlorine, Liquid:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
Ludlow Valve Mfg. Co., Inc.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.

Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

"METERMINDER" water meter box

"METERMINDER" is designed so that water meters can be read and serviced from the outside. In slab floor, basementless homes, installation is made through the wall just at the top of the foundation and can be done on old as well as new services. In homes with basements, installation is made through foundation with top of box at grade level. Normal heat loss through basement foundation or wall provides frost-free zone to keep meter and yoke from freezing. Fiberglas insulation is used to retard heat-loss. The cover of "METERMINDER" is made of durable, neutral gray, resin-rubber compound. This non-metallic material will never rust, rot or require painting. Meter is read through a plexiglass window. "METERMINDER" will effect tremendous savings in meter-reading time and promote goodwill. Eliminates call-backs and customer reading cards. Servicing labor is greatly reduced. "METERMINDER" is the solution to your great need for outside meter installations. Our representative will furnish specifications and prices. Just write or phone us.

ANDRICH WATER SPECIALTY CO.

A FEW TERRITORIES AVAILABLE FOR SALES REPRESENTATION BY MANUFACTURER'S AGENTS

15815 HAMILTON AVE., DETROIT 3, MICHIGAN • TUlsa 3-2000

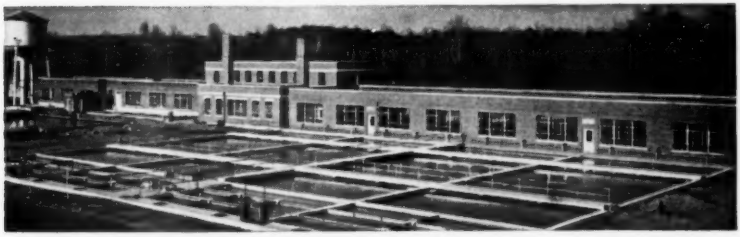
Roberts Filter Manufacturing Co.

DARBY, PENNSYLVANIA

WATER PURIFICATION EQUIPMENT

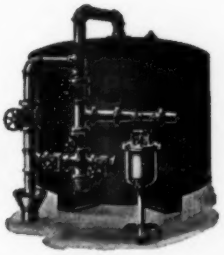
STANDARD OF QUALITY FOR MORE THAN 60 YEARS

WATER FILTRATION PLANTS and EQUIPMENT
GRAVITY FILTERS and EQUIPMENT—PRESSURE FILTERS (Vertical & Horizontal)—WATER SOFTENING EQUIPMENT
SWIMMING POOL EQUIPMENT



This 8 million gallon a day water treatment plant is typical of the many hundreds of Roberts-equipped installations throughout the United States, Canada and Latin America. We welcome the opportunity to cooperate with engineers on all types of water filtration equipment projects.

- **Dependability**
- **Experience**
- **Engineering Cooperation and Service**



Roberts Style L
Vertical Pressure Filter

SWIMMING POOL EQUIPMENT

This modern pool at Levittown, Pa., built by Levitt and Sons, Inc., is representative of the thousands of Roberts-equipped swimming pools. We produce a complete line of swimming pool recirculating plants and filtration equipment, backed by more than 60 years experience in the field of water purification.

Coagulant Aids:
Hagan Chemicals & Controls, Inc.
National Aluminate Corp.

Condensers:
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.
Worthington Corp.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
B-I-F Industries, Inc.—Builders
Foxboro Co.
General Filter Co.
Simplex Valve & Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

Corrosion Control:
Calgon Co.
National Aluminate Corp.
Philadelphia Quartz Co.
Southern Pipe Div. of U.S. Industries

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
E. H. Wachs Co.

Covers, Vault:
Ford Meter Box Co.
E. H. Wachs Co.

Desalinization Plants:
Emhart Mfg. Co., Maxim Div.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engineers and Chemists:
(See Professional Services)

Evaporating Equipment:
Emhart Mfg. Co., Maxim Div.

Feedwater Treatment:
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
Dicalite Div.
General Filter Co.
Johns-Manville Corp.
Monterey Sand Co.
Northern Gravel Co.
Permutit Co.
Stuart Corp.

Filters, Incl. Feedwater:
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Permutit Co.
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Cochrane Corp.
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.
Olin Mathieson Chemical Corp.
Tennessee Corp.

Fluoride Feeders:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
B-I-F Industries, Inc.—Builders
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Mueller Co.
Southern Pipe Div. of U.S. Industries

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Photovolt Corp.
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.

save fittings, pipe joints and space

FORD RINGSTYLE* VALVES

Ford Ringstyle construction is a feature developed by Ford to attach the meter coupling nut to the service valve. This eliminates extra couplings, fittings and pipe commonly used in old style meter settings. Puts valve about 2" closer to meter, saving valuable space, particularly in a meter box.

Ford Ringstyle Valves for connecting to copper have beveled end built into basic design to eliminate cumbersome, loose washer. Fitting is threaded to take standard copper tube nut.

Ringstyle Valves are made in straight and angle patterns, of inverted-key and compression types and for iron and copper connection. Free samples available to water works men.

FOR BETTER WATER SERVICES

FORD

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

Hays Mfg. Co.
Hersey-Sparling Meter Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Filtration Plant, Pumping Station, Transmission Line:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Burgess-Manning Co., Penn Instruments Div.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Motors, Electric:
Allis-Chalmers Mfg. Co.
Ideal Electric Co.
Worthington Corp.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
James B. Clow & Sons
Southern Pipe Div. of U.S. Industries
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
American Hard Rubber Co.
Morgan Steel Products, Inc.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
American Hard Rubber Co.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Shell Chemical Corp.
Southern Pipe Div. of U.S. Industries

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
E. H. Wachs Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
National Aluminate Corp.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
National Aluminate Corp.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

CONVENTIONAL 18-FOOT CAST IRON PRESSURE PIPE

GRIFFIN-20 COUNCIL BLUFFS

10% FEWER JOINTS!

CUT PIPE INSTALLATION COSTS WITH

GRIFFIN 20*

CAST IRON PRESSURE PIPE IN 20-FOOT LENGTHS!

"Give us longer pressure pipe lengths to help hold down rising labor costs involved in pipe installation!"

That was the overwhelming demand of water works operators, city engineers, consultants, and piping contractors in the Plains States, according to market surveys conducted by the Griffin Pipe Division of Griffin Wheel Company.

To answer this need, Griffin has developed the **Griffin-20** . . . a complete line of 20-foot cast iron pressure pipes in the popular 4- to 12-inch diameter size range. Compared to conventional 16-foot and 18-foot lengths, this modern 20-foot length means *over 10 percent fewer joints* . . . and *that* means that less time is required to install **Griffin-20** cast iron pressure pipe!

Griffin is the first American foundry to manufacture cast iron pressure pipe in 20-foot lengths, cast by the Delavaud process in this popular size range. A complete selection of pipe joints is offered, including the patented Bell-Tite *slip-on, mechanical joint,* and *bell and plain end.* All pipe will be either cement-lined to full specification thickness, or half thickness, as required.

Not only will the new *length* save money for cast iron pressure pipe users throughout the Midwest . . . the strategic location of the Griffin Pipe plant at Council Bluffs will also effect substantial savings in *shipment* time and money!

Take advantage of all these economies. The *next* time you have a cast iron pipe installation . . . *contact Griffin!*

*"Griffin-20" is a trademark of Griffin Wheel Company

GRIFFIN PIPE DIVISION

GRIFFIN WHEEL COMPANY • COUNCIL BLUFFS, IOWA

GRIFFIN PIPE DIVISION COUNCIL BLUFFS

Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Inc.

Tank Painting and Repair:
Koppers Co., Inc.
National Tank Maintenance Corp.
Taylor Iron Works

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.
Taylor Iron Works

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey-Sparling Meter Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Reconditioning and Formation Testing:
Halliburton Oil Well Cementing Co.
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1959 AWWA Directory.

here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafi., Lima, Peru

Why this "magnetic" meter has no troublesome stuffing box

With Rockwell Sealed Register meters you will never again need to service worn or leaky stuffing boxes—for there are none: A simple, powerful magnetic coupling transmits every motion of the measuring chamber direct to the register without a mechanical coupling or seal.

Stuffing box maintenance is only one way you'll save with these revolutionary meters. You'll gain substantially through a construction in which only two moving parts operate in water—all others run snug, dry and lubricated for life in a hermetically sealed register housing.

Too, the sealed register construction assures that condensation or dirt can never collect underneath the glass to make meter reading difficult. And you can even run this meter under water without harm.

The cost for all this? No more than you pay for ordinary meters—less in fact than for meters fitted with special type registers. Get facts today, write Rockwell Manufacturing Company, Pittsburgh 8, Pa.

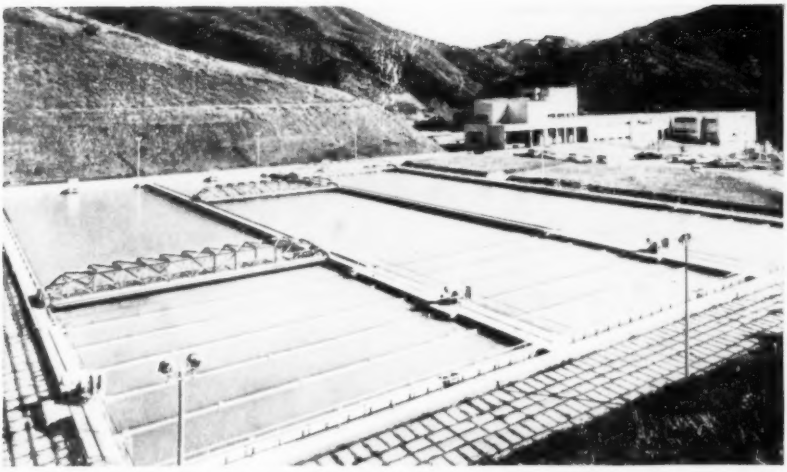
POWERFUL MAGNETIC DRIVE

Illustrating how the driver magnet (held in hand) revolves around a watertight compartment at base of register to push the follower magnet, which in turn drives the register shaft.

SEALED REGISTER METERS

another fine product by

ROCKWELL



La Mariposa Water Treatment Plant: Dorrco Monorakes in rear basins; Flocculators in foreground.

CARACAS, VENEZUELA

Dorr Monorakes, Flocculators Boost Capacity

Caracas, with a population over one million and rated one of the world's fastest growing cities, recently completed a second addition to its La Mariposa Water Treatment Plant to increase capacity from 16 to 80 MGD.

The original plant was equipped with two Dorrco Squarex Clarifiers, 115′ square by 14′ s.w.d., and two Type "T" Flocculator units for basins 115′ long by 40′ wide by 11′ s.w.d.

To achieve the five-fold boost in capacity, Dorr-Oliver equipment was again chosen. The recent additions comprise three Type "A" Dorrco Monorakes for basins 202′ long by 65′ wide by 14′ deep, three Type "T" Dorrco Flocculators 50′ long by 65′ wide by 11′ deep, and twelve new Filters.

DESIGN ENGINEERS: Instituto Nacional de Obras Sanitarias.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

Squarex, Dorrco—T.M. Reg. U.S. Pat. Off.

DORR-OLIVER

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

Mayor R. Dewey Stearns says . . .

"SAGINAW'S MODERN WATER SYSTEM PAYS FOR ITSELF 365 DAYS A YEAR!"

"Good, fresh water—with its quality protected by miles of Transite Pipe—helps make Saginaw, Michigan, a wonderful place to live . . . work . . . and do business!"

"Busy shoppers in downtown Saginaw give an accurate indication of the active business climate our citizens enjoy . . ."

"Diversification is important to our economy. And each industry—from automotive products and heavy machinery to baking equipment and agriculture—*thrives on water . . .*"

"Because good water is vital to the life and growth of Saginaw, we go to one of the best raw water sources in the Midwest . . . to Lake Huron for a limitless supply of the purest water."

"A water system must undergo continuous expansion to meet growing domestic, industrial and fire protection needs. Transite Pipe has helped Saginaw expand economically and efficiently since we first used it in 1933."

J-M Transite Pipe safeguards water purity . . . helps keep cost low!

Made of tough, durable asbestos-cement, Transite® Pipe cannot rust . . . stays clean to protect the quality and purity of the water it carries!

Transite also saves tax dollars for other uses—it is installed quickly, economically . . . its smooth interior keeps pumping costs low . . . its Ring-Tite® Coupling conserves precious water. And, of course, Transite Pipe is noted for its unusually long life.

For information on how Transite Water Pipe (and Transite Sewer Pipe, too) can serve your city, write Johns-Manville, Dept. JA-1, Box 14, New York 16, N. Y.

Your prosperity, welfare, safety, depend on good water . . . and plenty of it. Now is the time to support your water program . . . and water utility officials.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS